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Exploring the Moon with LROC-NAC Stereo Anaglyphs

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Abstract

The Lunar Reconnaissance Orbiter Camera Narrow Angle Camera (LROC NAC) operating on the Lunar Reconnaissance Orbiter (LRO), has returned over 500,000 high resolution images of the surface of the Moon since 2009 [1]. The NAC acquires geometric stereo image pairs of the same surface target on subsequent orbits by rolling the spacecraft off-nadir to achieve stereo convergence. Stereo pairs are generally acquired close in time (2 to 4 hrs), to minimize photometric differences. An anaglyph is a qualitative stereo visualization product formed by putting one image from the stereo pair in the red channel, and the other image in the blue and green channels, so that together the pair can be viewed in 3D using red-blue or red-cyan glasses. LROC NAC anaglyphs are produced automatically, so the stereo information is readily interpretable, in a qualitative sense, without the need for intensive computational and personnel resources, such as is required to make digital terrain models (DTM).

1. Introduction

The NAC consists of two separate cameras, with separate optics and focal planes, and with pointing offset across the spacecraft ground track to widen the field of view (dual coverage of 5 km from 50 km altitude). The NAC cameras acquire images in a push broom sense, using a charge-coupled device (CCD) line detector with one wideband visible light filter. NAC pixels can be summed to increase signal-to-noise. The size of a typical NAC image (summing=0, L or R) is 5064 pixels across by (typically) 52,224 pixels long. The L and R frames overlap in the center by ~124 pixels, but are slightly offset in the along track direction. Depending on orbit altitude, pixel scale can range from ~0.25 to 2.1 m (minimum 0.5 m along track due to smear) [1].

The anaglyph is constructed of two images with an adequate stereo convergence angle, displayed in two colors (red and blue, or cyan), so that viewing with red-blue glasses allows one image to be seen with the left eye (red lens) and the other to be seen with the right eye (blue lens). As long as the stereo separation is not too extreme or too shallow, the brain can perceive depth in the image. Although it is not straightforward to make measurements on such images (due to variations in convergence angle, image size, distance from viewer, etc.) anaglyphs do provide a valuable tool for visualizing the morphology of the Moon. This quick visualization tool in turn assists in selecting scenes for labor intensive DTM production.

2. Building the Anaglyph

LROC-NAC anaglyphs are generated using a similar method to the High Resolution Imaging Science Experiment (HiRISE) anaglyphs of Mars. (http://hirise.lpl.arizona.edu/anaglyph). HiRISE is similar to the LROC NAC in that it is also a push broom camera and takes stereo images in a similar fashion. However, the NAC is different in that each observation has two images taken with different optics. If the NACL and NACR images are not well registered along their center overlap region, these discontinuities will cause 3D artifacts. Recent improvements to camera pointing [2] and spacecraft position knowledge [3] have made automatic alignment the NAC-L and NAC-R images possible.

2.1 Selecting the stereo pair

The first step in generating a NAC anaglyph is selecting a pair of NAC observations that overlap and are taken with a sufficient stereo convergence angle. The viewing angles and orbital parameters are queried to determine the stereo convergence angle, as well as which image is the “left eye” and which is the “right eye.”

2.2 Registering NAC-L and NAC-R

Each NAC frame is map projected using a polar stereographic projection with the longitude of projection being the left edge of the stereo left eye image. Map projection also resizes the images if necessary to account for differences in pixel scale due to viewing geometry. The projection uses a

spherical shape model, since we do not wish to correct for topographic distortions. Once the NAC left and right images are mosaicked together, the two stereo observations are brought into closer alignment by running the Integrated Software for Imagers and Spectrometers, version 3 (ISIS3) program *coreg* (http://isis.astrogeology.usgs.gov/Application/presentation/Tabbed/coreg/coreg.html), which finds an approximate line and sample translation. It is critical that the features in the image have little to no separation in the line (vertical) direction. Parallax in the sample (horizontal) direction is intrinsic to the viewing geometry, and is how the perception of 3D is achieved.

2.2 Image assembly

Once the two stereo images are aligned, they are stacked into a 3-band image, where the 1st band is the red channel containing the left-eye mosaic, and the 2nd and 3rd bands (green and blue) contain the right-eye mosaic. A non-linear stretch is applied for contrast normalization between the two images, to facilitate recognition of topography in relatively dark regions of the image without saturation of the bright areas. The image cube is then converted to standard format (to be determined) and browse images to be posted on the LROC web site as Reduced Data Records (RDRs).

6. Summary and Conclusions

Pipeline production of anaglyphs made from LROC NAC stereo images is in development. These images will provide high resolution 3D viewing of the Moon to the public and the lunar science community. NAC anaglyphs will be available on the LROC web site at http://lroc.sese.asu.edu.

References

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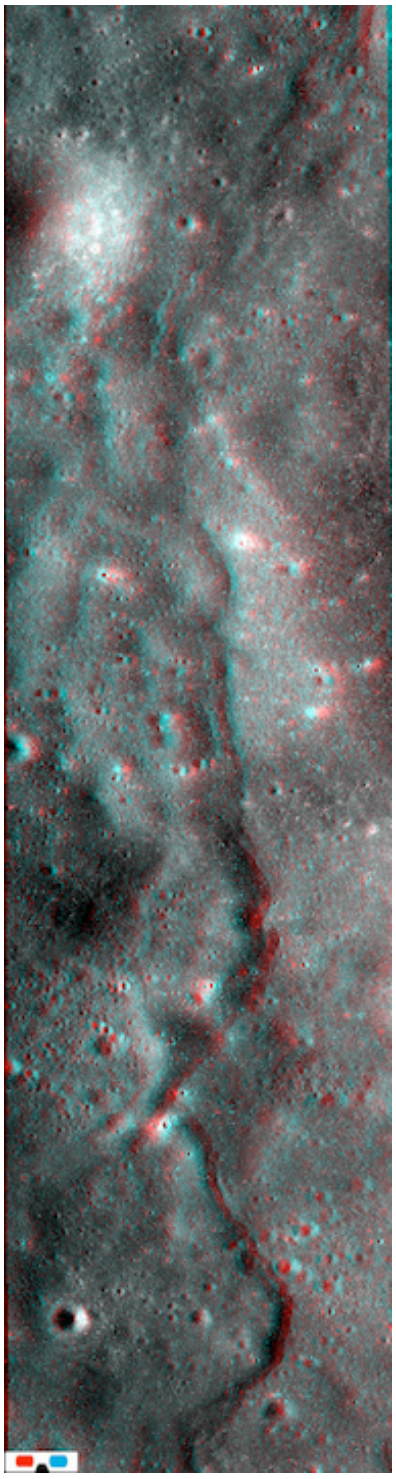

Figure 1: Anaglyph from NAC frames M151596778L and M151603560L. Scene is ~6 km across. North is up.