ENHANCED 3D SURFACE GENERATION IN THE AMES STEREO PIPELINE. S. McMichael¹, O. Alexandrov¹, and R. Beyer²,¹ NASA Ames Research Center (scott.t.mcmichael@nasa.gov), ²Sagan Center at the SETI Institute.

Introduction: With the release of version 2.6 of the Ames Stereo Pipeline (ASP) we now offer two new stereo algorithms, SGM and MGM, that significantly improve the quality of terrain models produced by ASP. Our software has also has gained the ability to take advantage of images captured under multiple lighting conditions and generate/enhance stereo or LIDAR terrain models by using Shape from Shading (SIS). In addition, ASP can now create surface models from images without known camera position and orientation using structure from motion (SFM).

Semi-Global Matching and More Global Matching: Semi-global matching (SGM) is a proven stereo algorithm with widespread popularity [1][2]. More Global Matching (MGM) is a variation of SGM that can produce superior output at the cost of longer run-time and higher memory usage [3].

ASP’s implementation includes two significant modifications to the original algorithms. First, ASP uses a hierarchical disparity search method that restricts the search range on subsequent levels in order to minimize memory usage. This approach is very similar to the tSGM method[4]. Second, ASP performs a 2-D disparity search instead of the more common 1-D search. This eliminates the need to perfectly rectify the input images (which can be difficult for pushbroom and some extraterrestrial sensors) but does come with a significant run-time and memory cost. We have also been able to improve our results by using a ternary census transform and texture-aware filtering as described in [5].

SGM and MGM Evaluation: The performance of these algorithms is usually much better than a block matching approach applied to the same terrain:

Operation IceBridge. NASA’s IceBridge flights use an off the shelf consumer camera mounted on a propeller driven aircraft to take pictures of Antarctica, Alaska, and Greenland. On the left is a patch of terrain generated by ASP’s block matching algorithm and on the right is the same region generated using the MGM algorithm. The noise in the flat regions of the image has been reduced, there are fewer holes, and the elevated regions are sharper.
**Extraterrestrial.** The new algorithms can be used on any image data supported by the USGS ISIS software [6]. The example below is from an Apollo 15 image pair, with the block matching output on the left and the MGM output on the right.

![Image](image1.png)

**Shape From Shading:** SfS allows ASP to enhance terrain obtained from regular stereo methods or gridded lidar [7]. The level of detail produced by SfS is comparable to the detail present in the input images, allowing it to restore features that may not be present in the input terrain model. It can also remove interpolation artifacts and automatically correct for camera errors and shadows. All cameras supported by ISIS can be used with SfS.

**SfS Evaluation:** SfS has been extensively tested with data from the Moon and also with Phobos and Charon datasets. SfS works best if used with multiple images of the terrain acquired under diverse lighting conditions. Shown on the left is a gridded terrain produced from LOLA data and shown on the right is the terrain after processing with SfS. In the SfS image you can clearly see more craters and terrain features. Several artifacts present in the LOLA data have also been removed.

![Image](image2.png)

**Structure from Motion:** ASP has acquired the ability to create camera models and subsequently terrain models from images that lack camera metadata. This includes data sets such as historic satellite imagery, aerial imagery, and hand-held camera imagery. ASP solves for position and orientation using a structure from motion implementation from the Theia library [8]. ASP can solve for unknown camera intrinsics and has several methods to find the absolute position in world coordinates depending on what sources of information are available.

### References:


### Additional Information: ASP (Linux and OSX binaries) can be downloaded at the following location: [http://irg.arc.nasa.gov/ntg/stereo](http://irg.arc.nasa.gov/ntg/stereo). Also there is the documentation and information about how to subscribe to the mailing list. ASP is open source, released under the Apache 2 license, and all source code is available on GitHub.