Geophysical Research Abstracts
Vol. 16, EGU2014-16110, 2014
EGU General Assembly 2014

Merged Shape from Shading and Shape from Stereo for Planetary Topographic Mapping

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Digital Elevation Models (DEMs) of the Moon and Mars have traditionally been produced from stereo imagery from orbit, or from the surface landers or rovers. One core component of image-based DEM generation is stereo matching to find correspondences between images taken from different viewpoints. Stereo matchers that rely mostly on textural features in the images can fail to find enough matched points in areas lacking in contrast or surface texture. This can lead to blank or topographically noisy areas in resulting DEMs. Fine depth detail may also be lacking due to limited precision and quantisation of the pixel matching process.

Shape from shading (SFS), a two dimensional version of photoclinometry, utilizes the properties of light reflecting off surfaces to build up localised slope maps, which can subsequently be combined to extract topography. This works especially well on homogeneous surfaces and can recover fine detail. However the cartographic accuracy can be affected by changes in brightness due to differences in surface material, albedo and light scattering properties, and also by the presence of shadows.

We describe here experimental research for the Planetary Robotics Vision Data Exploitation EU FP7 project (PRoViDE) into using stereo generated depth maps in conjunction with SFS to recover both coarse and fine detail of planetary surface DEMs. Our Large Deformation Optimisation Shape From Shading (LDOSFS) algorithm uses image data, illumination, viewing geometry and camera parameters to produce a DEM. A stereo-derived depth map can be used as an initial seed if available. The software uses separate Bidirectional Reflectance Distribution Function (BRDF) and SFS modules for iterative processing and to make the code more portable for future development. Three BRDF models are currently implemented: Lambertian, Blinn-Phong, and Oren-Nayar. A version of the Hapke reflectance function, which is more appropriate for planetary surfaces, is under development.

Examples will be shown of shape from shading results for the Apollo 17 and other landing and rover sites, particularly on Mars. We will discuss how to determine automatically which components of the resulting DEM are best generated by stereo matching, which by SFS, and how the two should be combined. We will also discuss how the choice of BRDF model and its parameters can affect the outcome. The research leading to these results has received funding from the European Community's Seventh Framework Programme (FP7/2007-2013) under grant agreement number 312377 PRoViDE.