Shape-from-Shading (SfS) on the Moon

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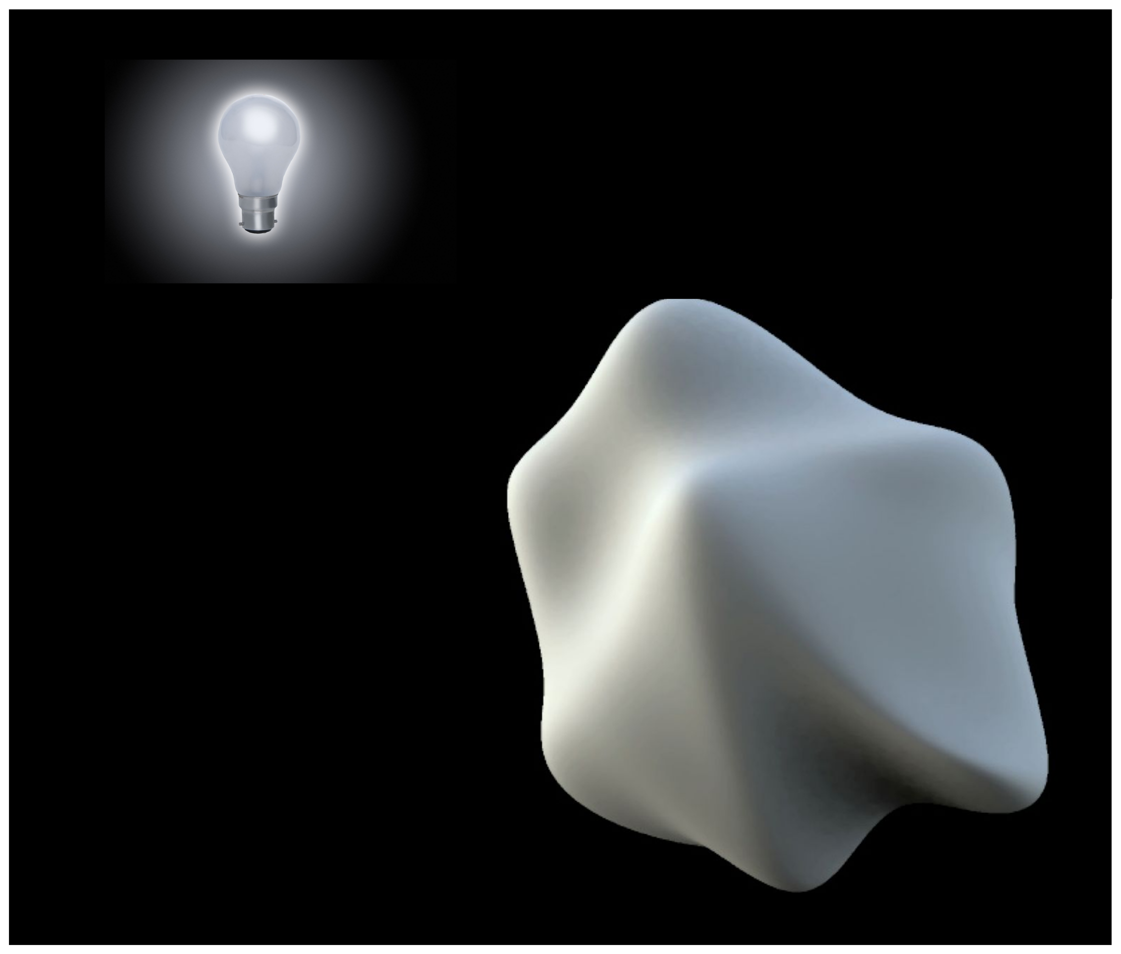
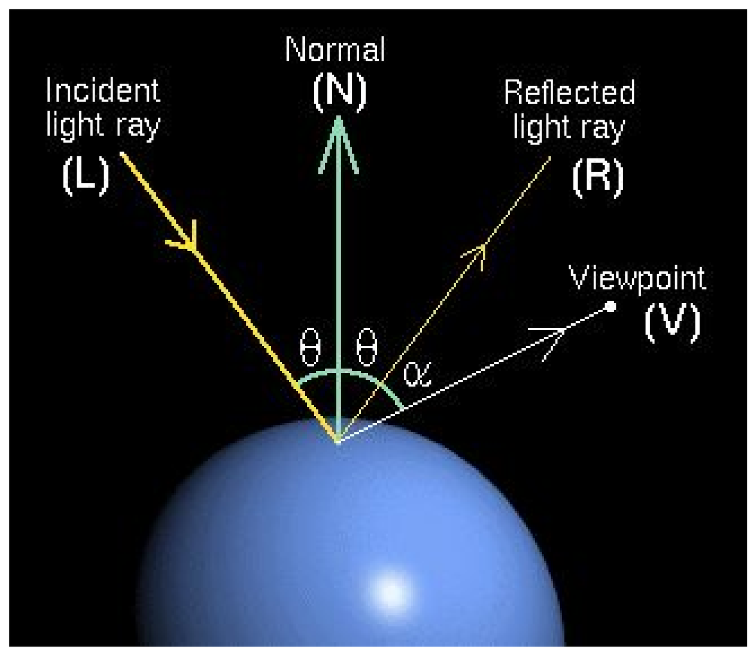
- Create high-resolution Lunar terrain starting with an initial guess from stereo/LIDAR
- Use information from multiple images with different lightning conditions to extract detail
- Model reflectance, albedo, camera exposures, their positions and orientations, and shadows
- Handle both equatorial and polar regions
- Validate accuracy using ground truth
- Use for large-scale terrain reconstruction
- Supported by the Resource Prospector Mission (RPM) which aims to put a lander close to Moon's South Pole
- Builds on/relates to earlier work in IRG (Ara Nefian, Uland Wong) and latest literature

Key observation: a light source creates shades on a shape due to angle-dependent reflection. We solve the reverse problem: from shades to the shape.

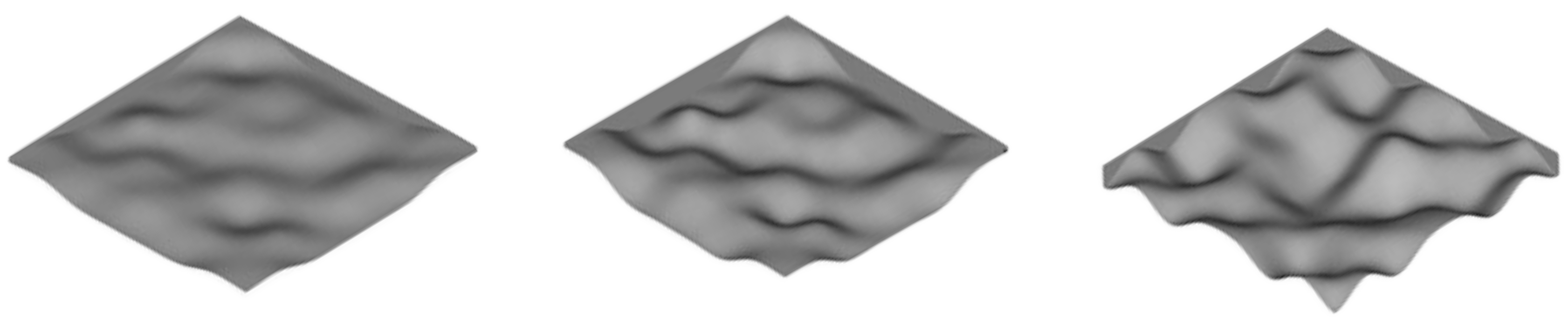




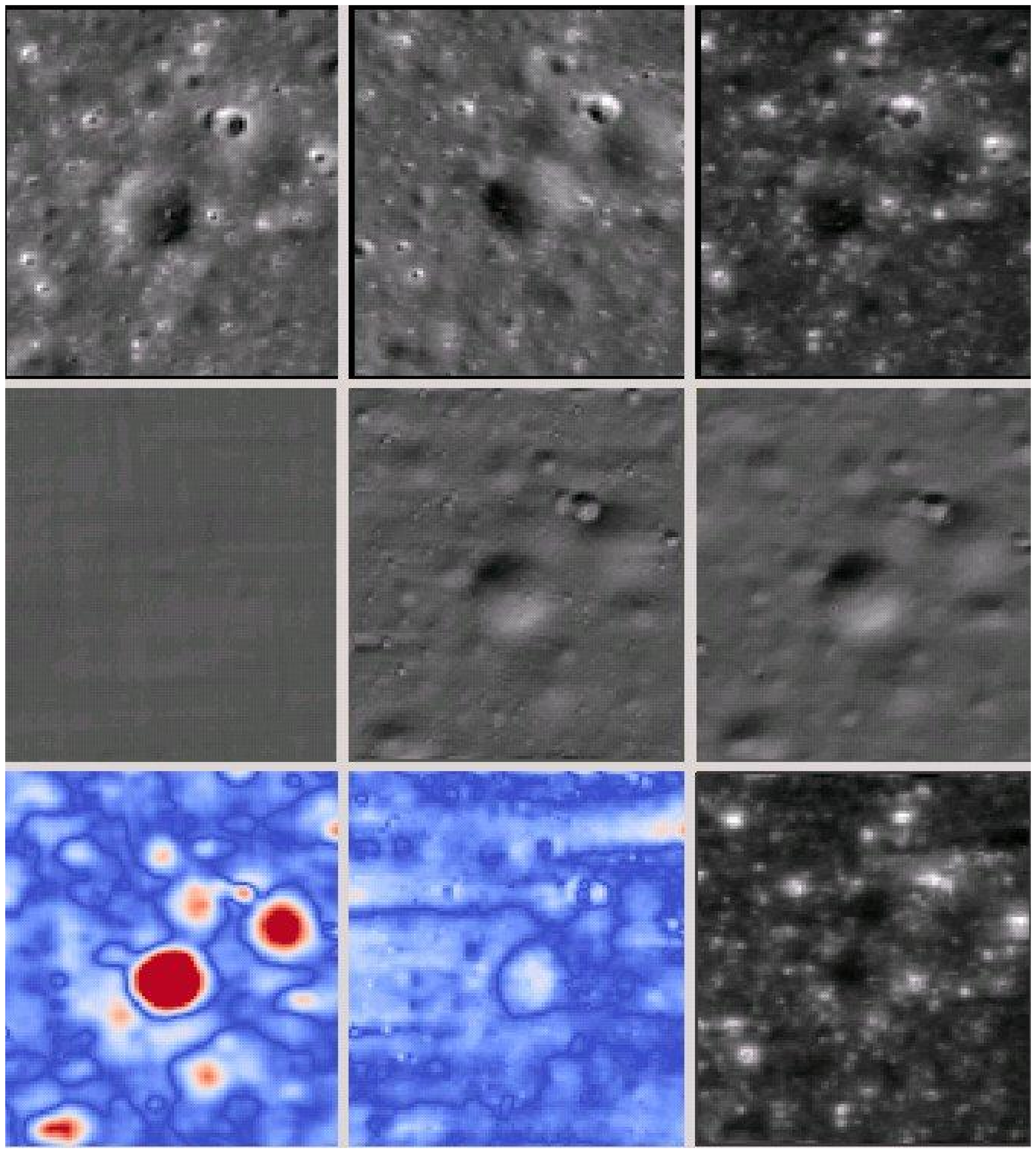
The functional to minimize

$$\iint \sum_k \left[I_k(\phi)(x,y) - T_k A(x,y) R_k(\phi)(x,y)\right]^2 + \mu \left\|\nabla^2 \phi(x,y)\right\|^2 + \lambda \int \left[\phi(x,y) - \phi_0(x,y)\right]^2 \, dx\, dy$$

The shape is refined iteratively



Use 10x coarser LRO NAC input images for SfS (row 1). Initial guess, SfS result, and validation with 1x terrain (row 2). Error before and after SfS, and solved albedo (row 3).



Before and after SfS, and comparison with LOLA using 1x LRO NAC images (1 meter/pixel)