Neural 3D Reconstruction of Planetary Surfaces from Descent-Phase Wide-Angle Imagery

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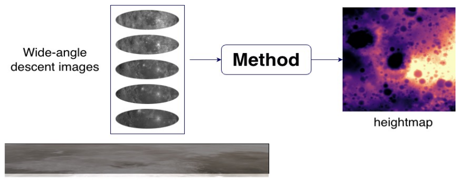
Abstract



Why?

- Essential for studying past and ongoing geological processes
- Low-cost option for high-resolution terrain re-construction instead of using orbital or ground images

Challenges

- Strong radial distortion
- Limited parallax
- Near planar surface geometry
- Dominant single light source

Idea

- Use neural 3D representations to support this task
- Incorporating domain specific lighting models
- Stronger regularization near the descent point to enforce a flat surface without floaters

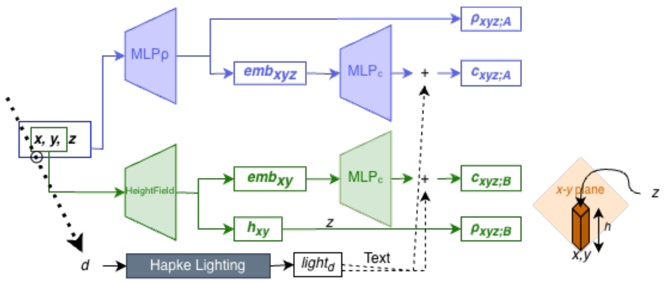
Project Page

Melonie de Almeida

Paul Henderson

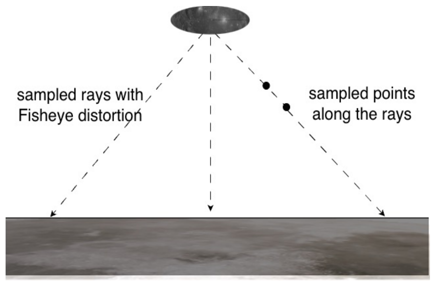
Methods

Representation



- *Our method uses two scene representations that each define the density and colour of sampled points (x, y, z) along the ray: the* ***NeRF representation*** *(purple) and* ***heightmap representation*** *(green).*

Optimization for a planetary object

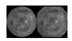


Fisheye Ray Casting*: maps each pixel through a wide-angle lens to a 3D ray using the lens's radial distortion model*

Targets: Ground truth wide-angle descent images

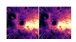
Losses

- **RGB Loss**



GT wide-angle RGB Vs rendered wide-angle RGB

- **Height Loss**

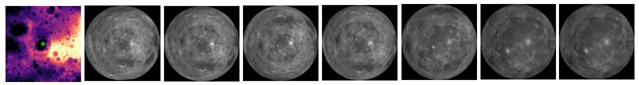


NeRF representation Vs heightmap representation

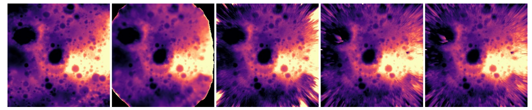
- **Distortion Loss** – minimize the spread of densities along the ray near the descent point

Experiments and Results

Lunar data

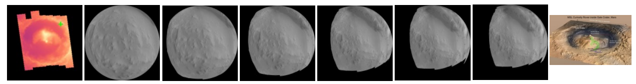


Results:

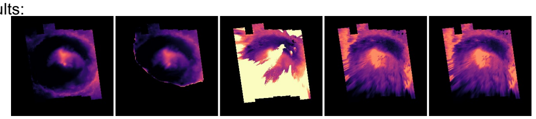


Ground Truth | *Metashape* | *NeRF* | *Ours-NeRF representation* | *Ours-heightmap representation*

Mars Data



Results:



Ground Truth | *Metashape* | *NeRF* | *Ours-NeRF representation* | *Ours-heightmap representation*

Dataset	Model	AED (m) ↓	RED (m) ↓	Coverage@0.1 (%) ↑
	Metashape	196.49	23.05	92.30
	Nerfacto	198.16	60.30	99.16
Moon	Ours	188.98	46.63	**99.52**
	Metashape	1388.09	72.64	70.32
	Nerfacto	9549.76	2022.66	49.88
Mars	Ours	1560.59	92.53	**95.58**

- *Our method achieves improved surface coverage while maintaining satisfactory elevation accuracy on both Lunar and Mars data.*