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Lunar Craters Modeled from the LROC Database for 3D Printing with Inclusive Educational Proposals

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Abstract. This work describes a procedure to process data from the Lunar Reconnaissance Orbiter (LRO) and create digital models for simulations and 3D printing of lunar surface features. Techniques were developed to enhance tactile experiences and add Braille captions. Several craters have already been modeled and replicated using molds. A method was also refined to produce Braille texts and tactile plaques attached to the models, providing scientific information for visually impaired individuals. The feasibility of these materials is being assessed in collaboration with an institution focused on inclusive education.

Resumo. Este trabalho apresenta um procedimento para operar com dados do Lunar Reconnaissance Orbiter (LRO) e gerar modelos digitais para simulações e impressão 3D da superfície lunar. Foram desenvolvidas técnicas para otimizar a experiência tátil e incluir legendas em Braille. Diversas crateras já foram modeladas e impressas, com moldes que permitem replicações. Também foi aprimorado um método para criar textos em Braille e placas táteis anexadas aos modelos, oferecendo informações científicas a pessoas com deficiência visual. A viabilidade desses materiais está sendo avaliada em parceria com uma instituição voltada à educação inclusiva.

Keywords. Moon – Teaching of Astronomy – Techniques: 3D Printing – Virtual observatory tools

1. Introduction and Goals

At an altitude of 50 to 200 km from the Moon, the Lunar Reconnaissance Orbiter (LRO) is a probe whose main objective is to conduct a large-scale instrumented survey of its surface. Among its instruments, three cameras (LROC) stand out, capturing images and spectra of intermediate and high resolution, achieving spatial separations better than 0.5 meters per pixel (Chin et al. (2007), Robinson et al. (2010)). Combined with stereoscopic techniques, three-dimensional images with resolutions of a few centimeters are produced Mazarico et al. (2011), composing a vast database with numerous uses, including scientific research, technical applications and for educational purposes (Node (2014), Francis (2022)).

The “Caravana Luar do Sertão” (CLdS) project, which promotes public telescopic observations in northeastern Brazil, benefits from these possibilities, as it has invested resources and personnel in designing educational methods, engineering solutions, and tactile materials for inclusion. Among these efforts, this work presents a procedure for accessing and manipulating data from these instruments, generating digital models for computational simulation of the lunar surface and for 3D printing.

The overall objective of this study (following (Gomes da Silva et al. 2024)) is to create methods and models obtained from observations with the LROC for the teaching, research, and outreach activities of the Caravana Luar do Sertão project (G0). To this end, the following specific objectives are established:

- G1 Establish methods using planetary models for using the LROC database;
- G2 Produce multisensory materials, especially exploring the concept of tactile astronomy;
- G3 Create video tutorials explaining procedures and activities;
- G4 Establish a collection of various lunar structures to be displayed in non-formal learning environments;
- G5 Experiment with procedures to highlight information about the lunar surface in order to emphasize specific educational interests;
- G6 Develop activities involving the handling of materials and measurement techniques;
- G7 Provide resources for dynamics and actions that involve the transfer of models to real observations, with inclusive possibilities.

2. Methodology

We started this work through the procedure created by the CLdS group for planetary models, including how to cover their surfaces with observations obtained by real probes (Lima & Scarano Jr. (2019); G1).

1. (a) For mold production, a specific crater is first located using the LROC QuickMap ACT (2024). Using the built-in Draw/Search tool, it is possible to (b) draw a polygon to delimit the region of interest. (c) Double-clicking the left mouse button on the polygon opens the Feature Inspector tab. In this tab, select "Other" to enable the 3D printing options. (d) The link "Export 3D Model" opens the 3D printing display window, which provides numerous customization options to visualize and export the file in a standard format. Particular attention should be given to the "Vertical Exaggeration" option, which allows the user to rescale the selenographic feature in a way that is useful for tactile applications.
2. (a) Import the file into Blender, taking care to change the scale to 10^{-4}, since the model is generated with the dimensions of the real crater. (b) It is necessary to generate a meshed cube, rescaled to be produce a rectangular prism, slightly larger than the model, specially in the height, in order to produce the mold. (c) Use the Boolean tools to subtract the crater model from a rectangular prism, thus generating a negative shape that serves as a mold. (d) At this stage, you can also control the vertical scale of the image, and thus produce craters with

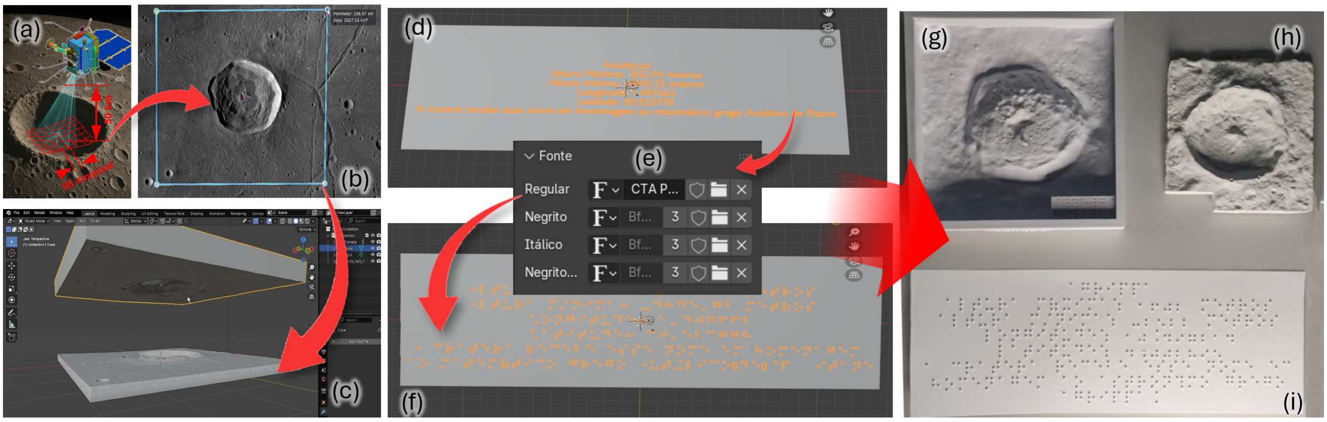

Figure 1. Sketch for the steps to produce the molds and Braille plaques. (a) LROC Sample; (b) Polygon on the QuickMap; (c) Subtracted prism for the imported crater; (d) Texts inserted over a 3d plaque; (e) Truetype text conversion to Braille CTAP characters. (f) resulting 3d Braile paque model; (g) 3d printed PLA mold, (h) alginate crater produced; (i) PLA Braille plaque.

more prominent tactile scales.The printing of the molds aims to provide a durable matrix of the same crater, while the molded objects can be handled and worn down as they are made available as materials for multisensory activities (G2).

3. Following the G2 goal, to produce the Braille plaques, (a) the texts are first prepared using information available in LROC, such as the origin of the respective crater's name. (b) In Blender, a plaque with the desired dimensions is created, which will receive the text in a Braille font adapted for Portuguese Egami (2025). (c) After placing the text, the solidify and remesh modifiers are applied to form the raised writing. Once the plaques conform to the ABNT standard ABNT (2020), they are 3D printed in PLA.
4. The 3D prints of the molds and Braille plaques follow the same procedure. (a) Files are exported from Blender as .stl format to a slicing software. This program is responsible for converting the modeled object into a set of instructions for 3d printing. (b) In this software, some presets are defined and can be changed for each object: for the molds and plaques, in addition to the material settings, in this case PLA filament, adjustments are made to how the printer executes the object's printing, in order to increase the precision and durability of the final results. The infill density is set to 15%, and the options for "precise walls" and "random seam position" are selected. (c) After these settings, new file is exported as G-code and sent to the printer, which should already be prepared with the filament.

The previous modeling procedures were compiled in a playlist ASTUTOS-UFS (2024) (G3). The resources used to obtain the data from the LROC database are in the first video. The second video present the steps for generating the molds for 3D printing using LROC data and 3D molds, employing Blender software. The third presents a generic procedure for modeling any map in grayscale levels, not limited only to the Moon. Finally, the last video, is dedicated to create the Braille plaques.

3. Results, discussions and conclusions

Based on the procedures and methods described in the previous section, it was possible to model various types of craters (from simple to complex) to compose a collection of craters and molds (including structures such as Shackleton, King, Triesnecker, Autolycus, Agrippa, Clavius, Plato, Tycho, Langrenus, and Kepler) and Braille plaques with the respective information and descriptions of each crater (G4).

By exposing this material to different light sources, one can illustrate the Moon's phases, explain crater visibility through contrast, and use the models to easily simulate measurements of lunar crater heights Silva et al. (2022) (G6).

Braille plaques enhance participation and learning for visually impaired people, supporting inclusive activities that connect models to real observations (G7). These interactions, first carried out with specialized university groups such as DAIN/UFS and BICEN/UFS, helped identify strengths and areas for improvement. Future plans aim to expand interventions beyond the university to reach new audiences.

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