

Technical Note

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Technical Note

Resource-Constrained 3D Volume Estimation of Lunar Regolith Particles from 2D Imagery for In-Situ Dust Characterization in a Lunar Payload

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Abstract

Future lunar exploration efforts rely on an improved understanding of regolith behavior, as evidenced by the adhesion problems encountered during the Apollo missions. The Lunar Payload, a compact lunar instrument developed in Poland, aims to assess the adhesion of lunar regoliths to various materials using an optical method chosen to meet strict mass constraints. We introduce and validate a resource-constrained optical method to estimate three-dimensional volumes of lunar regolith particles from two-dimensional imagery, using high-resolution micro-CT as ground truth. The approach supports in-situ surface characterization and dust-related risk assessment under the mass and power constraints typical of small payloads. Micro-CT scans were used to establish accurate reference volumes, and multiple geometric approximation methods were applied, including spherical, ellipsoidal, and cylindrical models, to derive volume estimates from a 2D representation. Comparative analyses demonstrate that ellipsoid-based models, particularly those that incorporate a fixed aspect ratio, provide the most accurate volume estimations. These findings offer a practical *in situ* methodology for analysing the volumes of regolith particles, thus advancing the capacity of the Lunar mission to characterise lunar adhesion of regolith particles and supporting broader efforts in lunar resource utilisation and habitat construction. To our knowledge, this is the first benchmarking of six 2D-to-3D volume models against micro-CT for lunar regolith adhesion applications. Our findings demonstrate that ellipsoid-based methods achieve the best results, offering a validated, efficient technique for in-situ dust characterization critical for future lunar missions.

Keywords: regoliths; image processing; experimental techniques; data reduction techniques; moon surface

1. Introduction

The Moon, often envisioned as a natural extension of Earth's space capabilities, is reachable within approximately three days. However, despite this proximity, direct human exploration has been limited to only 12 astronauts, as documented after the Apollo programme by Johnson et al. [1]. Nonetheless, its close proximity and the existing body of knowledge continue to make the Moon an intriguing subject for research and a promising foundation for a space-based economy, as noted by Crawford et al. [2].

More than five decades after the last human lunar landing in 1972 [3], interest in lunar exploration has been reignited. A new era of lunar exploration has emerged with an increasing number of private and governmental missions. This resurgence is largely driven by the pivotal discovery of water ice deposits on the lunar surface. Based on data from the Chandrayaan-1 probe, Pieters et al. [4] published a study detailing these findings, which profoundly altered our understanding of the lunar environment and its potential to support future human habitation and scientific endeavors.

1.1. Motivations and Science Objectives

Lunar regolith includes fine particles, characterised by irregular shapes as described by Isachenkov et al. [5]. The concept of In Situ Resource Utilisation (ISRU), as discussed by Meurisse and Carpenter [6] involves harnessing lunar regolith to manufacture structures and other essential commodities directly on the Moon using locally sourced materials. This approach significantly improves the efficiency and sustainability of lunar exploration and resource utilisation efforts as described by Guerrero-Gonzalez and Zabel [7]. ISRU enables the extraction of oxygen, hydrogen and metals [8], which can support long-term lunar habitation, according to Anand et al. [9]. The entire habitat structure could be constructed using sintered regolith, which exhibits promising properties for thermal storage and radiation protection [10,11]. Furthermore, 3D printing technology can facilitate this process, as demonstrated by Taylor et al. [12], and the direct production of solar panels on the Moon using local materials is considered feasible, providing a sustainable energy source, as suggested by Freundlich et al. [13]. As Lin et al. [14] describe, remote observations of the regolith have been conducted using orbiters such as the Lunar Reconnaissance Orbiter [15] and rovers, for instance, the Yutu-2 rover [16], and samples were brought back by the Apollo, Luna, and Chang'e missions. However, *in situ* observations remain limited. Without direct measurements, neither the formation processes nor the true properties of the lunar regolith can be fully understood, as noted by Plescia [17]. Moreover, the safe human operations that would benefit lunar science the most still rely on robotic missions that provide critical information, as noted by Crawford et al. [18]. Lunar regolith poses a significant threat to human and robotic exploration of the Moon, making it crucial to understand how to mitigate its effects. The fine, abrasive, and adhesive nature of lunar regolith caused significant damage to the equipment during Apollo missions [19,20]. The challenges for ISRU include managing the adhesion and abrasion effects caused by this material, as discussed by Cannon et al. [21]. The thickness of the lunar regolith varies across the Moon, averaging approximately 5 metres in the mare regions and 12 metres in the highlands, according to Shkuratov [22]. Its unique properties, shaped by distinct erosive processes, make lunar regolith significantly different from terrestrial sand [23].

One such initiative that will gather more information on lunar regolith adhesion is the Lunarix payload, a lunar research project developed by a research group from AGH University of Krakow in partnership with Orbital-Space. This payload was selected through a global competition organised by Orbital-Space and is now scheduled to be aboard Astrobotic's Griffin Mission 3, which is expected to launch no earlier than 2027 [24]. The primary objective of the Lunarix mission is to gather data on how lunar regolith adheres to different materials *in situ*. To achieve this, the payload employs an optical system that captures 2D images of adhered particles for subsequent analysis.

This study introduces techniques for approximating the three-dimensional (3D) volumes of lunar regolith particles based on two-dimensional (2D) image analysis, addressing a critical requirement for the Lunarix mission. Precise determination of particle volume is particularly significant in experimental methods aimed at measuring particle adhesion forces. Because the mass of individual regolith particles depends directly on their volume assuming the density is known, accurate volume assessments are fundamental for reliable adhesion force calculations. For instance, in centrifugal adhesion measurement methods commonly employed in regolith particles adhesion research [25–27], the maximum adhesion force is calculated based on particle mass, rotational speed, and radius of rotation. Given that such methods often necessitate rapid estimations of particle volume from 2D imagery due to experimental constraints, the accuracy of 3D volumes significantly influences the reliability of adhesion measurements.

This paper is structured as follows; The first section introduces the scientific background and motivations behind the study, highlighting the challenges of lunar exploration and the importance of accurately approximating the volume of lunar regolith particles. An overview of the Lunarix payload follows, detailing the mission design, operational concept, and key components. Subsequently, the materials and methods are described, including the experimental procedures, image acquisition, and post-processing techniques used for regolith analysis. Various volume calculation methods are then

presented to estimate particle volumes from 2D images. Finally, the results are discussed in detail, comparing the performance of different methods and evaluating their implications for future lunar exploration and in situ resource utilisation.

2. Lunar Payload Overview

The Lunar payload is a sub 1U-class, 3D-printed, deployable system for in-situ optical sensing under mass (200 g) and power (0.5 W) budget, illustrating how compact instrumentation can deliver exploration-relevant regolith characterization within smallsat constraints. Its primary structure is made of CRP Windform XT 2.0, a space-qualified material used in CubeSats and deployers [28]. The integrated structure includes a bus and a spring-loaded hatch supporting a camera and a dual-section LED lighting system. These components face a tiltable material sample plate, aligned with the camera using a stepper motor and monitored by Hall-effect and optical endstop sensors. A render is shown in Figure 1. The electronics-onboard computer, power unit, and motor controller-are housed within the bus. The payload operates by deploying the hatch, contacting the lunar surface with the sample plate, illuminating the contact area, capturing images, and transmitting data to Earth. It complies with stringent mission constraints: 200 g total mass, a maximum power consumption of 0.5 W and a compact 1U form factor.



Figure 1. Render of the Lunar Payload.

3. Materials and Methods

Due to constraints related to mass, power, and resource limitations, optical methods are employed to analyse the adhesion of lunar regolith particles in situ. The calibration method for the Lunar payload uses a 3D scanner, specifically a GE phoenix v | tomex | m micro-CT system. This approach aims to establish a precise calibration method for quantifying adhered particles of the regolith analogue. By determining the 3D volume of particles deposited on PEEK samples, it is possible to estimate the total volume of adhered material. The calibration is performed only once and serves to validate the methodology used to approximate the 3D volume of regolith particles, thereby ensuring the reliability of subsequent optical measurements.

Lunex Technology LX-M100 is a Mare-type lunar regolith simulant. The mineralogical composition of this simulant is presented in Table 1.

Table 1. Mineral composition of Lunex technology LX-M100 regolith analog.

Mineral phase	Volume fraction [vol%]
Plagioclase feldspar (Labradorite)	38.4
Pyroxene (Augite)	41.9
Olivine (Forsterite)	18.4
Titanomagnetite	1.0
Alkali Feldspar	0.3

3.1. Experimental Procedure

The experiment involved the following steps:

1. Sieving the regolith to obtain a controlled particle distribution below 100 μm .
2. Depositing the regolith onto 2 mm PEEK disk samples, which were then mounted on a glass rod.
3. Attaching a piece of low-density foam to the glass rod, to which the sample with regolith was affixed using hot glue.
4. Placing the glass rod in a self-centering, rotating holder to ensure stable positioning during scanning.
5. Testing two different PEEK samples (B and C), with multiple scans per sample:
 - Sample B: four scans,
 - Sample C: three scans.

PEEK was selected due to its compatibility with the measurement technique, specifically its effective X-ray transparency. Scans were performed using a dual-lamp GE Phoenix v|tome|x|m tomograph, during which each sample was rotated 360° to ensure comprehensive visualization. The sample was mounted on a glass rod and positioned within a self-centering holder inside the scanner. Centrifugal detachment tests conducted between scans caused a gradual reduction in particle volume, visible across successive images. Differences in the total number of scans between samples B and C are attributable to variations in the visualization approach. Sample C included an initial pre-dusting scan, which was subsequently excluded from comparative analysis. In contrast, scanning of sample B commenced after the dusting procedure, resulting in four scans for sample B and three scans for sample C, all of which were included in the analysis. The reconstructed 3D greyscale model represents the levels of X-ray absorption, which are largely dependent on material density. The voxel size achieved in this study was 2 μm^3 . Each sample scan took approximately one hour.

3.2. Post-processing

After exportation, the samples were initially aligned using VGStudio and exported to the .raw format. The next step was to import them into Avizo Thermo Fisher 2020.3, which enabled segmentation and 3D visualisation of the samples. The first step involved importing the raw file and performing an initial representation to verify data integrity. Once confirmed, a median filter and then interactive thresholding were applied to segment the regolith, leveraging its distinct X-ray permeability relative to PEEK. The result is shown in Figure 2.

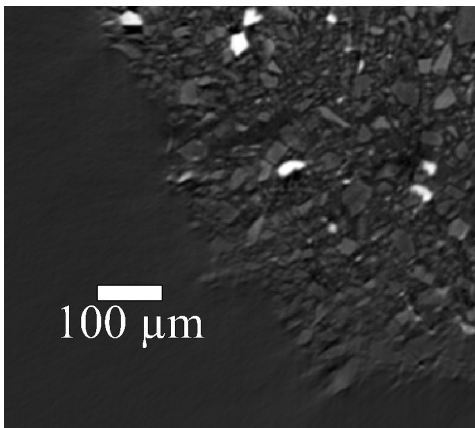


Figure 2. Part of slice scan after median filtering.

Due to variations in atmospheric conditions, such as pressure fluctuations that affect scan intensity, each sample was manually analyzed to ensure consistency. Subsequently, the ‘separate objects’ function was applied to detach clustered particles. Following segmentation, labeling analysis was conducted, and the 3D volumes of the regolith particles were reconstructed. The overall process is depicted in Figure 3.

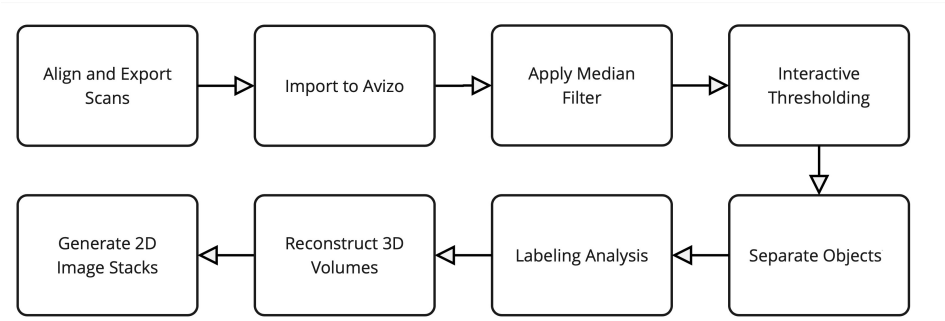


Figure 3. Workflow of the image segmentation and 3D reconstruction process.

To enable quantitative analysis, image stacking was used to create a 2D representation of the segmented volume. The resulting image, shown in Figure 4, illustrates the segmentation results. Each color represents an individual particle. Following segmentation, the processed data-including particle volumes and shape descriptors-were exported for subsequent analysis.

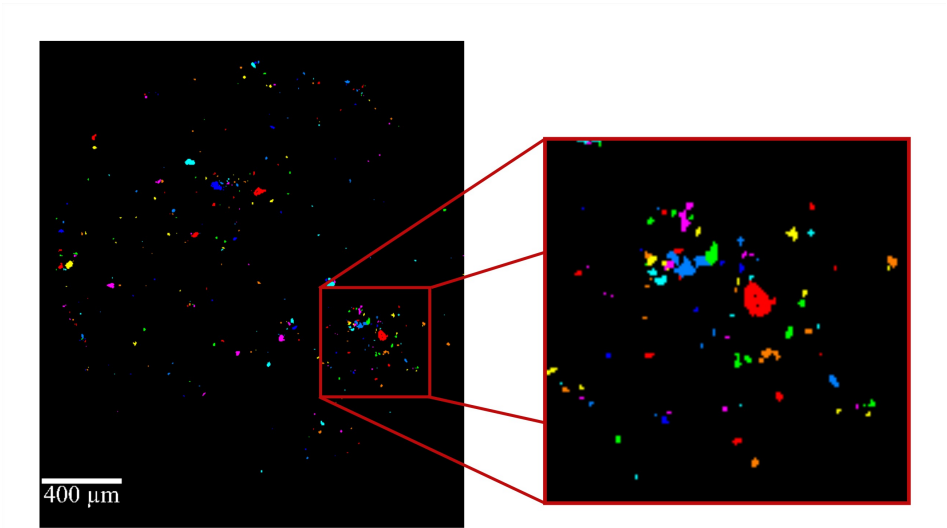


Figure 4. Image stacking representation of sample 3B. Different colors correspond to segmented individual particles.

Subsequent processing was performed in MATLAB 2024b, where the images were imported and converted to greyscale. To ensure accurate measurements, the scale was manually determined for each image, enabling the calculation of the pixel-to-micrometre ratio. A circular region of interest was applied to isolate the relevant portions of each image, minimising the influence of background noise. The process is presented in Figure 5.

The scale factors used for conversion of exported images from Avizo are presented in Table 2.

Table 2. Scale factors used for pixel-to-micrometer conversion.

Image	Scale Factor (μm/pixel)
1B	3.8462
2B	3.7031
3B	3.8462
4B	3.8462
1C	3.7736
2C	3.6980
3C	3.7031

For particle segmentation, an adaptive thresholding approach was employed to facilitate binarization, followed by the application of the SLIC algorithm (Simple Linear Iterative Clustering) [29], which generated approximately 2300 superpixels per image with a compactness factor of 20. To refine the particle boundaries, the edges between the superpixels were set to zero in the binary image. The described process is presented in Figure 5.

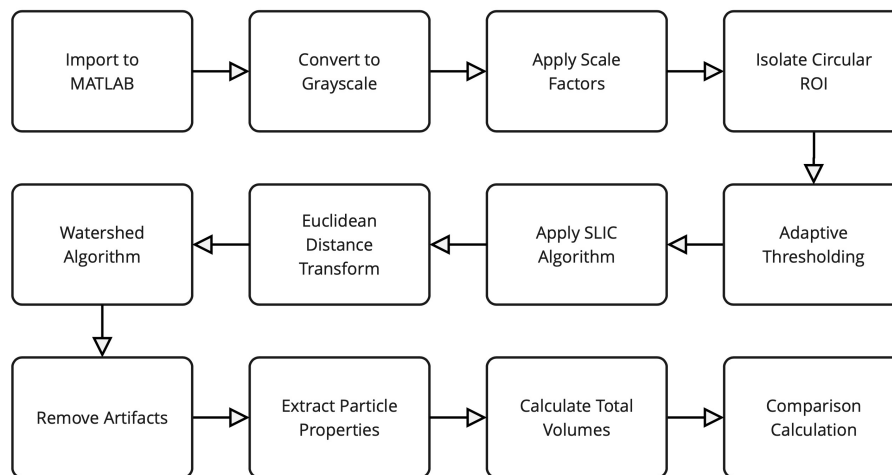


Figure 5. MATLAB image processing workflow.

In order to effectively separate touching particles, the Euclidean distance transform of the inverted binary image was computed, followed by the application of the watershed algorithm. A similar approach to that presented by Sun and Luo [30] was used to effectively address the problem of oversegmentation. Extended minima with a height threshold of 0.5 were imposed to identify particle cores, ensuring accurate segmentation. The watershed lines were subsequently set to zero in the binary image to finalise the particle delineation. Finally, any artifacts smaller than one pixel were removed through an area opening to enhance the segmentation accuracy.

Once segmentation was completed, the geometrical properties of the individual particles were extracted using the `regionprops` function. This allowed for the measurement of key morphological parameters, including particle area, major axis length, and minor axis length, initially in pixel units. These values were then converted to micrometres using the image-specific scale factor. The total particle volume per image was determined by adding the individual particle volumes, allowing for direct comparison with the reference data set and facilitating an evaluation of the accuracy of the measurement.

4. Volume Calculation Methods

To quantify the volume of particles identified in the segmented images, six methods are used, each based on different geometric assumptions about particle shape. Let A_i represent the physical area of the i -th particle (in μm^2), derived from the area of the pixel scaled by the square of the scale factor ($scale_factor^2$), where $i = 1, 2, \dots, N$ and N are the total number of particles in an image. For methods using Feret diameters or ellipse axes, additional measurements are defined: $d_{max,i}$ and $d_{min,i}$ are the maximum and minimum Feret diameters, and $l_{major,i}$ and $l_{minor,i}$ are the lengths of the major and minor axes of the fitted ellipse, all in physical units (μm). The total volume for each method is computed as follows:

$$V_{total,method} = \sum_{i=1}^N V_{i,method},$$

where $V_{i,method}$ is the volume of the i -th particle according to the specified method. In the following, each method is described and its corresponding volume equation for a single particle is provided.

4.1. Sphere Method

This method follows the principles outlined by [31], where the estimation of particle size approximates particles as spheres for simplified calculations whose projected area equals the measured area A_i . The radius r_i is derived from $A_i = \pi r_i^2$, so $r_i = \sqrt{\frac{A_i}{\pi}}$. The volume is then:

$$V_{i,\text{sphere}} = \frac{4}{3}\pi \left(\sqrt{\frac{A_i}{\pi}} \right)^3 \quad (1)$$

4.2. Ellipsoid with Fixed Aspect Ratio

Here, particles are modelled as ellipsoids ([32]), with two equal semi-axes and a third axis scaled by a fixed aspect ratio $AR = 0.5$, as specified in the technical datasheet of the employed regolith simulant. Assuming the projected equatorial area is $A_i = \pi a_i^2$ (where $a_i = b_i$) visible in the Figure 6, and the third semi-axis is $c_i = AR \times a_i$, the volume is derived as:

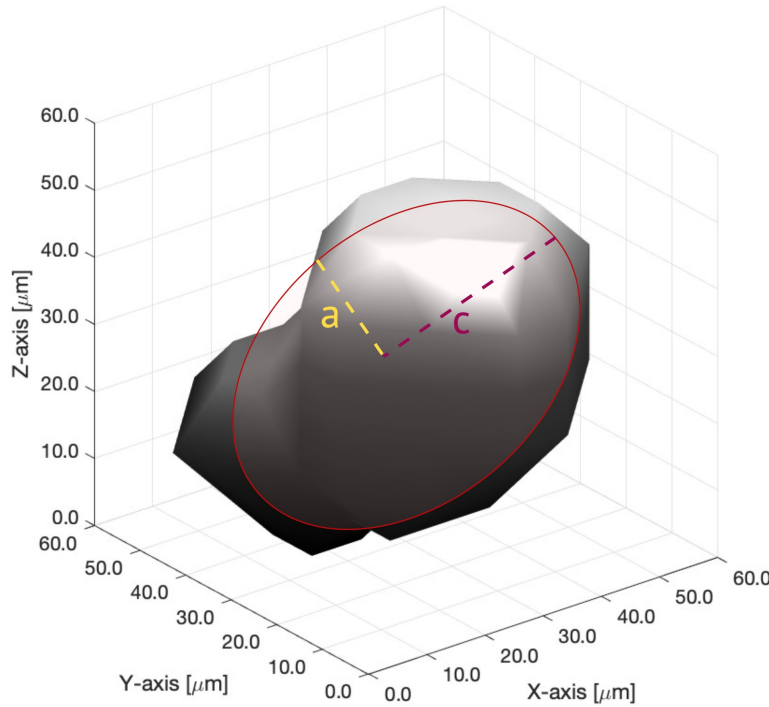


Figure 6. Ellipsoid approximation showing semi-axes relations.

$$V_{i,\text{ellip1}} = \frac{4}{3\sqrt{\pi}} \times AR \times A_i^{3/2}, \quad \text{where } AR = 0.5 \quad (2)$$

This formulation adjusts the spherical volume by aspect ratio, reflecting an oblate spheroid when $AR < 1$.

4.3. Feret Method

This approach uses the maximum and minimum Feret diameters to approximate each particle as an ellipsoid ([33]). The maximum Feret diameter $d_{\max,i}$ is the longest distance between two points in the convex hull of the particle, and the minimum Feret diameter $d_{\min,i}$ is the smallest width perpendicular to this direction, both sized to physical units. The semi-axes are assigned as $a_i = \frac{d_{\max,i}}{2}$, $b_i = c_i = \frac{d_{\min,i}}{2}$, yielding:

$$V_{i,\text{feret}} = \frac{4}{3}\pi \left(\frac{d_{\max,i}}{2} \right) \left(\frac{d_{\min,i}}{2} \right)^2 \quad (3)$$

4.4. Cylinder Method

Particles are approximated as cylinders with a base area equal to the projected area A_i and a height equal to the diameter of a circle with that area. If $A_i = \pi r_i^2$, then $r_i = \sqrt{\frac{A_i}{\pi}}$, and the height is $h_i = 2r_i$. The volume is:

$$V_{i,\text{cylinder}} = A_i \times 2\sqrt{\frac{A_i}{\pi}} \quad (4)$$

4.5. Voxel Method

This method modifies the cylinder approach by applying an empirical scaling factor of 0.4, possibly to adjust for overestimation or to align with voxel-based measurements. The volume is:

$$V_{i,\text{voxel}} = 0.4 \times A_i \times 2\sqrt{\frac{A_i}{\pi}} \quad (5)$$

4.6. Adaptive Ellipsoid Method

This method models each particle as an ellipsoid with semiaxes derived from the lengths of the major and minor axes of the fitted ellipse ($l_{\text{major},i}$ and $l_{\text{minor},i}$), with the third axis set as half the minor axis. The semiaxes are $a_i = \frac{l_{\text{major},i}}{2}$, $b_i = \frac{l_{\text{minor},i}}{2}$, $c_i = \frac{0.5 \times l_{\text{minor},i}}{2} = \frac{l_{\text{minor},i}}{4}$, so:

$$V_{i,\text{adaptive}} = \frac{\pi}{12} l_{\text{major},i} l_{\text{minor},i}^2 \quad (6)$$

4.7. Percentage Difference Calculation

The percentage difference is used to compare the volume estimated by each method with the reference volume for each image. It quantifies the relative error of the estimate as a percentage. The calculation is defined as follows:

For each image i and volume estimation method m , the percentage difference $P_{m,i}$ is calculated using the formula:

$$P_{m,i} = \left(\frac{|V_{m,i} - V_{\text{true},i}|}{V_{\text{true},i}} \right) \times 100 \quad (7)$$

where:

- $V_{\text{true},i}$ represents the reference volume of the particles in image i ,
- $V_{m,i}$ is the volume estimated by method m for image i ,
- $P_{m,i}$ is the percentage difference for method m on image i , expressed as a percentage.

The above methods have been applied for the experimental data processing.

5. Results

The volume estimation results for each image are presented in Table 3, where the estimated volumes are reported along with the percentage differences from the reference volume. The closest estimation for each sample is underlined.

A heatmap-style colouring scheme has been applied to indicate the accuracy of each method:

- **Green (low error, $\leq 20\%$):** represents the most accurate estimations.
- **Yellow (moderate error, $20\% - 60\%$):** represents estimations with moderate deviations.
- **Red (high error, $> 60\%$):** indicates significant deviations from the reference volume.

Table 3. Comparison of volume estimation methods for each image. Volumes are in μm^3 , with the percentage differences from reference volumes indicated below estimated values. The closest estimations (lowest percentage) in each row are underlined.

Image	Particles	Reference Volume	Sphere	Ellipsoid_AR1	Feret Method	Cylinder	Voxel	Adaptive Ellipsoid
1B	1987	78,390,888	64,477,518 (17.75%)	32,238,759 (58.87%)	102,714,739 (31.03%)	96,716,277 (23.38%)	38,686,511 (50.65%)	32,636,083 (58.37%)
2B	2784	4,790,720	11,204,390 (133.88%)	5,602,195 (16.94%)	17,333,278 (261.81%)	16,806,585 (250.82%)	6,722,634 (40.33%)	5,688,187 (18.73%)
3B	709	836,632	1,665,194 (99.04%)	832,597 (0.48%)	2,600,915 (210.88%)	2,497,791 (198.55%)	999,117 (19.42%)	915,138 (9.38%)
4B	277	195,112	389,406 (99.58%)	194,703 (0.21%)	477,892 (144.93%)	584,109 (199.37%)	233,644 (19.75%)	185,263 (5.05%)
1C	2806	3,395,408	8,843,351 (160.45%)	4,421,675 (30.23%)	14,421,407 (324.73%)	13,265,027 (290.68%)	5,306,011 (56.27%)	4,883,668 (43.83%)
2C	116	20,328	56,541 (178.15%)	28,270 (39.07%)	61,914 (204.58%)	84,812 (317.22%)	33,925 (66.89%)	27,513 (35.35%)
3C	38	31,376	28,921 (7.82%)	14,460 (53.91%)	28,671 (8.62%)	43,382 (38.27%)	17,353 (44.69%)	12,588 (59.88%)

For images 3B and 4B, the smallest percentage errors were observed, with Ellipsoid_AR1 achieving deviations below 1%. In contrast, images 1B and C1 exhibited greater variations between methods, with errors exceeding 99% for some approaches. The Cylinder and Sphere methods generally produced the highest overestimations, while the Adaptive Ellipsoid and Ellipsoid_AR1 methods provided more accurate results in most cases. The Voxel method demonstrated moderate errors ranging from 19% to 66%, depending on the image. Across all images, Ellipsoid_AR1 achieved the most consistent accuracy, particularly for smaller volumes.

Continuing on these results, sample 2B showed relatively low errors with Ellipsoid_AR1 (16.94%) and Adaptive Ellipsoid (18.73%), whereas the Sphere method drastically overestimated by 133.88% and the Cylinder method soared to 250.82%. Likewise, for sample 2C, the Adaptive Ellipsoid approach produced the smallest error (35.35%), followed closely by Ellipsoid_AR1 (39.07%), while the Cylinder approximation reached 317.22%. Conversely, sample 3C offers a rare instance where the Sphere method yielded the lowest error (7.82%). Although ellipsoid-based models generally excel-particularly Ellipsoid_AR1.

6. Conclusions

This study evaluated six methods for 3D volume approximation of lunar regolith particles, with ellipsoid-based approaches proving most accurate. These findings improve the ability of the LunarIS mission to study regolith adhesion *in situ*, supporting future lunar exploration and ISRU applications.

Adhesion measurement is a key aspect in the future of lunar exploration. During the Apollo era, numerous problems with regolith greatly impeded moon exploration. Adhesion and its mechanisms differ significantly from those on Earth: the high-vacuum Moon environment eliminates water-related capillary effects, leading to a fundamentally different behaviour of lunar regolith particles. To prepare for these challenges, extensive experiments must be performed in simulated environments and then on the Moon.

Many novel techniques have been developed, but adhesion forces typically depend on the mass of the particles, which makes it crucial to assess their volume. Among them is the LunarIS payload that uses a camera to visualise the adhered particles. Optical methods are frequently used in such studies because they yield quick and low volume data. However, 3D visualisation is far more accurate but requires high-performance computing and advanced equipment. Despite these requirements, it produces substantially more precise volume information. In the context of regolith particles volume evaluation, Barker et al. [27] used Feret length to estimate the volume of the particles under the assumption of sphericity; however, their results show that this approach is imprecise. Another example is presented by Oudayer et al. [34], who also assume particle sphericity and derive volumes

from a diameter measure. Similarly, [25] used particle sphericity for volume calculation. Ilse et al. [35] employed a cross-sectional diameter to define an equivalent spherical diameter for volume estimation. A narrower particle size distribution can also be achieved by sieving through two meshes, enabling the use of a particle counter analyser or spherical simulants to represent the regolith. Wohl et al. [36] adopted such a strategy.

Ellipsoid_AR1 employs a constant aspect ratio. This method fits our data set well. However, when the mean value of the aspect ratio is unknown, the Adaptive Ellipsoid method provides an alternative to calculate volume without a predefined ratio.

Most adhesion studies still rely on spherical volume approximations, which often introduce significant errors. In samples 1B and 1C, many particles overlapped, preventing the optical method from capturing regolith grains beneath the top layer. As shown in Figure 7, a side-view micro-CT reconstruction reveals distinct differences in the distribution of regoliths in samples. Sample 1B contains the highest amount of regolith, while sample 4B contains the least. In particular, samples 1B and 2B exhibit substantial particle layering, further emphasizing the limitations of optical methods in densely packed samples.

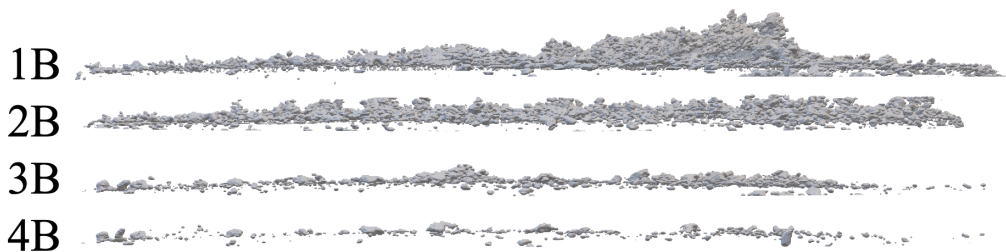


Figure 7. Side-view micro-CT reconstruction illustrating the regolith particle layering in sample B.

Regolith grains are highly irregular, and the accuracy of measurement strongly depends on the orientation of the particles. In 2B, more grains were exposed, which yielded better measurements. For 3C, which contains only 38 regolith grains, the error was larger for Ellipsoid_AR1, whereas the spherical approach produced the smallest error. Although ellipsoid-based methods can underestimate volume when the particle count is small, they remain the most suitable if the aspect ratio is known. The Adaptive Ellipsoid method produces similar results and may also be considered. These findings illustrate that certain datasets with few particles or unusual size distributions can favour simpler shapes. Overall, simpler geometries (e.g. spheres, cylinders) often lead to significant overestimations, whereas more flexible ellipsoid-based methods provide superior and more consistent accuracy across diverse sample sizes.

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During the preparation of this study, the authors used ChatGPT and DeepL for spelling checks and language clarity. The authors have reviewed and edited all generated content and take full responsibility for the final version of the manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

ISRU	In Situ Resource Utilization
CT	Computed Tomography
PEEK	Polyetheretherketone
ROI	Region of Interest
LED	Light Emitting Diode
TVAC	Thermal Vacuum
AR	Aspect Ratio
SLIC	Simple Linear Iterative Clustering
VGStudio	Volume Graphics Studio
MATLAB	Matrix Laboratory
GE	General Electric

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