VISUALIZATION OF FUSED STRUCTURE FROM MOTION AND MICRO X-RAY COMPUTED TOMOGRAPHY DATA SETS FOR NOVEL 3D VIRTUAL ASTROMATERIALS SAMPLES COLLECTION OF NASA'S APOLLO LUNAR AND METEORITE SAMPLES.
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Introduction: Our team continues to develop streamlined processes to collect, process and visualize new high-resolution precision photography (HRPP) and X-ray computed tomography (XCT) data of NASA's Apollo Lunar and Antarctic Meteorite samples for the 3D Virtual Astromaterials Samples (3DVAS) Collection project. The goal of the 3DVAS project is to create a digital database of research-grade 3D models of combined HRPP and XCT datasets for 60 of NASA's Apollo Lunar and Antarctic Meteorites, which will be available to researchers and the public via NASA's Curation website [1, 2, 3, 4, 5, 6, 8, 9]. In this abstract we are reporting successful fusion of the two datasets for Apollo Lunar Sample 79115,0 into one coordinate system using an improved technique from our first efforts [4, 8]. We used HRPP and XCT data acquired from Lunar Sample 79115,0 to develop and further our procedure in combining the two datasets. 79115,0 is classified as a medium gray soil regolith breccia, was collected during Apollo 17 on the rim of the Van Serg Crater [2] and is currently stored at NASA Johnson Space Center's Lunar Sample Laboratory Facility in the Astromaterials Acquisition & Curation Office [7].

Objective: The main objective is accurate fusion and subsequent visualization of two unique data sets - 3-dimensional Micro X-Ray Computed Tomography (XCT) internal composition data and a Structure-From-Motion (SFM) high-fidelity, textured external polygonal model of Apollo Lunar Sample 79115,0. The developed process utilizes innovative all-in-one functionality now available in off-the-shelf software, providing a platform to "slice through" a photo-realistic rendering of a sample to analyze both its external visual and internal composition simultaneously.

Data & Methods: The HRPP used to create the SFM models was captured by our cross-disciplinary team at JSC [1-6]. The imagery of 79115,0 was collected using a Hasselblad H3D-60 digital camera with 80mm and 120mm lenses. 240 of the collected 60 megapixel HRPP images (8956 x 6708) were processed using off-the-shelf 3-D SFM software Agisoft PhotoScan. A high-resolution textured polygonal model of 79115,0, in a Wavefront OBJ file format with an associated Material Template Library surface shading file, was output from PhotoScan. The textured polygonal model served as a high-fidelity representation of the lunar rock sample structure and its external texture [1-6, 9].

XCT data was collected by the University of Texas Austin High-Resolution X-ray CT (UTCT) Facility on 22 June 2016, and a total of 1,929 reconstructed 16-bit TIFF (2-D) image slices of pixel dimension 1027 (width) x 1284 (height) were generated. Volumetric element (voxel) scale data was documented by UTCT to be 46.3 micrometers. 3-D reconstruction of 79115,0 from the image slices was performed in VGSTUDIO MAX (VGS-MAX).

Initially, both XCT and SFM data sets reside in non-coincident coordinate systems. The prior workflow for fusion of SFT and XCT data sets of Apollo Lunar Sample 60639 required use of three off-the shelf software packages to perform XCT reconstruction and XCT and SFM data fusion and fit analysis [4, 8]. Manual scale adjustments of the SFM model of 60639 were performed in Autodesk 3ds Max, and automatic registration and fit analysis of the SFM model to the XCT isosurface model were performed in InnovMetric PolyWorks®. Workflow optimization efforts led us to discover and apply new processes for data fusion within VGS-MAX. Functionality within VGS-MAX allows for import of textured OBJ models as well XCT image stacks. As a result, our current workflow now employs VGS-MAX as an all-in-one XCT and SFM model registration and visualization software package.

The process of data fusion requires calculation of the six degrees of freedom (6DoF) transformation from the SFM model's coordinate system into the XCT coordinate system. Just as exercised in the initial data fusion process [8], the XCT coordinate system is defined as the reference, and the 6DoF transformation is applied to the SFM model. In VGS-MAX, the 79115,0 XCT data is processed into an isosurface model that serves as an empty shell representation of the sample, fit to the SFM model, also an empty shell representation of the sample. Within VGS-MAX, application of the best fit registration algorithm to SFM and XCT isosurface models yielded very good registration results.

Once the textured SFM model of the external surfaces of 79115,0 was registered to the XCT isosurface model, a process for creating single "slice" visualization of the sample was developed. In VGS-MAX, clipping box and clipping plane functions were applied to the XCT and SFM models, respectively, to control the visibility of the data. A clipping box function was applied to the XCT 3-D reconstruction data set and parameters were set to retain visibility of a single XCT 3-D reconstruction slice, the "examination" slice, in the XY plane. To achieve this effect, the scale of the clipping box in the x-axis was set to the XCT data voxel scale (46.3 microns). By default, the clipping box was aligned parallel to the XCT reference coordinate system. The examination slice location was set by adjusting the X position coordinate of the clipping box.

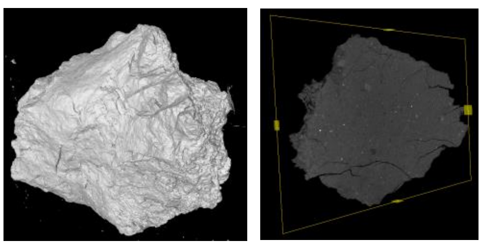

Figure 1: Before (left) and after (right) application of a clipping box to the XCT 3-D reconstructed data of 79115,0 in VGS-MAX

The X position was documented and used for SFM clipping plane definition. A clipping plane function was applied to the SFM model and parameters were set to hide the portion of the SFM model up to the examination slice along the X axis.

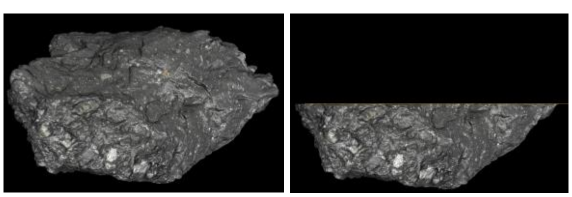

Figure 2: Before (left) and after (right) application of a clipping plane to the registered SFM model of 79115,0 in VGS-MAX

The result of the application of a clipping box to the reconstructed XCT data and a clipping plane to the registered SFM model was a single slice 3-D visualization of 79115,0, a fused render of the exterior surface texture and interior composition of 79115,0.

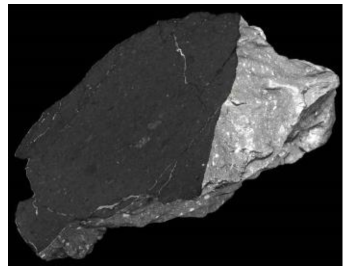

Figure 3: Single slice visualization of 79115,0 fused XCT and SFM data sets in VGS-MAX

Results & Discussion: Through this effort, a streamlined process for XCT 3-D reconstruction, XCT/SFM data fusion and slice visualization within a single software package, VGS-MAX, has been developed. After export of the registered SFM model from VGS-MAX, metrics of the SFM model to XCT isosurface model registration will be assessed in another software package, CloudCompare. The VGS-MAX best fit registration algorithm has yielded accurate fusion of 79115,0 XCT 3-D reconstruction and SFM model data sets. Metrics on the application of the algorithm to SFM and XCT data sets of Lunar Samples with less complex surface topography than 79115,0 will be assessed in the development of other Lunar Sample fusion data products.

The results allow for a novel visualization of 79115,0 and the rest of the 3D VAS Collection using data acquired with high-resolution modern photography and X-ray CT data acquisition systems, to be served on NASA's Astromaterials Acquisition and Curation website: https://curator.jsc.nasa.gov.

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