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Structure-from-Motion, Capturing Geological Samples

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In Development Share

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ABSTRACT

Structure-from-Motion (SfM) is a photogrammetry process that creates 3D models from overlapping 2D images. This protocol focuses on its application related to geological and geophysical samples. The samples includes fossil, hand samples and rocks. This is a recommended practice to be used later for the publication on United States Geological Survey website.

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Introduction

1 ***What is it?***

Structure-from-Motion (SfM) and photogrammetry is a recent application in the earth science community. SfM is the representation of physical samples as a 3D model produced from a series of overlapping 2D images collected from multiple angles about the sample or subject of interest. Research and application of photogrammetry have created space for various creations, ever-evolving software, and platforms where communities of 3D model creators publish their work(s). There are many options to develop a 3D model of a physical object, including "Optical/photogrammetry, radar, thermal, structure from motion, and acoustic techniques" (Harvey et al., 2017; Westoby et al., 2012; Zlatanova, 2008)." https://www.sciencedirect.com/science/article/pii/S0098300417301772?via%3Dihub. This protocol will focus on photogrammetry related to geophysical samples; rock cores, hand samples and fossils.

*Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

1.1 ***History***

These Structure from Motion processes were adapted from terrain analysis to the preservation of physical samples. There has been an increase in the creation of 3D models from physical samples in response to the changing work environment during the COVID-19 pandemic (Andrews er al., 2020). With the implementation of SfM, classrooms can study multiple samples virtually, increasing the variety and accessibility of geological samples. Students and researchers also have the opportunity to gain experience and technical skills with photogrammetry software in the classroom, and remote environments. Sourced from Teaching with Digital 3D Models of Minerals and Rocks

1.2 ***Value of SfM***

Remote/Virtual benefits:

- The preservation and curation of these physical samples have proven useful in times where physical contact may be restricted.
- Virtual access of physical samples helps maintain the integrity, prevention of loss, and accessibility of rock cores, hand samples, and fossils.
- Reduces travel costs to view samples.
- Increases access to financially/physically challenged parties.

Photogrammetry:

- Technical skills with photogrammetry software; This recommended practice can be helpful with photogrammetry in terrain analysis, etc.
- Used in museums, specifically within paleontology.

Minimum Standards

2 ***Overview***

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- In order to successfully create a high-quality 3D model of a physical sample, considerations for equipment, software, environment, sample resolution, and publishing platform, are necessary.

2.1 ***Equipment***

1. Camera and tripod
2. Two ring flash lighting--- provides even lighting
3. Class 10 SD card
4. Link for suggested CPU for photogrammetry: What is the Best CPU for Photogrammetry 2019
5. Standardized colorbar is necessary to calibrate images, such as Amazon.com: Kodak Color Separation Guide and Gray Scale (Q-13, 8" Long): Camera & Photo. Colorbar may not be necessary for fossilized specimens.
This link provides an example of use:
6. Lens polarizer to limit reflections (if using a full-frame camera)
7. Backup battery, if using full days worth of shooting
8. Shooting tent
9. Tools for markers (sharpie, chalk, stickers)
10. Rotating platform/turntable
11. Clay--- for staging physical sample

Example computer configuration:
"Recommended configuration for computer: 32 GB of RAM, an Nvidia video card with 4GB of Vram, and a hard drive of 2TB. Unity team use CPU intel i7-5960x, 64 GB of RAM, 980 GTX, 2TB hard drive." Cited by
Unity Photogrammetry Workflow

2.2 ***Software---*** *List of suggested modern photogrammetry software below*

- All3dp 2021 Suggested Photogrammetry Software

2.3 ***Environment***

Goal: Create a clean, organized environment to dedicate a table, with room for equipment. See steps 3.1 for more about staging the model.

- Physical samples can vary in size, shape, material, etc.
- The process of staging a sample can vary from specimen to specimen.
- When creating a space dedicated to staging, consider staying out of direct sunlight and ambient lighting. This allows complete control of the lighting equipment.
- The setup should be on a steady surface with no disturbances from other machines or furniture.

2.4 ***Publishing---*** *List of platforms for publishing*

There are plenty of options and platforms for publishing models (usually advertised as a platform for selling), below are a few links with suggestions.

- 8 Best Places Where to Sell Your 3D Model
- This link provides a search engine for previously published models: 3D Find It
- 50+ Websites to Download 3D Models for Free

Workflow/Procedure/Process

Overview

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3 The goal of this procedure is to efficiently produce a 3D model of a geological sample, that is FAIR (Findable, Accessible, Interoperable and Reusable).

3.1 ***Staging the model;***

- *Note: Higher lighting allows for lower iso; resulting in better quality images*

1. Check that all materials and equipment are gathered.
2. Place your shooting tent on a stable surface/table.
3. Place ring lights on opposite ends of the shooting tent.
4. Place round turntable inside the open shooting tent;
   - To help guide and ensure that photos are being taken with overlap, you may label/mark the turntable with even distances between them. Note: It is helpful to mark one spot on one side of the turntable the #1 (or any designated shape/ #), and the direct opposite side the #2, so you know where you begin and end.
5. Wipe/clean/dust the sample before staging.
6. Place the sample in an upright position on a mound of clay, for stable placement.
7. Set up the camera on the stable tripod, centered, facing the stage where the sample is placed.
8. After collecting photos of the sample, you will reposition the sample about the clay.
   - This optimizes capturing the entire sample. (i.e: If you place the sample upright on the clay mound, you are now potentially missing another angle, or unable to capture the bottom portion of the sample.)

10. Wipe down the sample and rotating table to remove any clinging clay or residue.
11. Carefully store away samples and clean up the equipment.

3.2 ***Capturing images:***

1. Take at least three photos at a time.
2. The second and third photos should have two-thirds of an overlap.
3. Continue all around the object sample.
4. Once the images have been acquired of the object/sample at all available angles, the photos can be imported into a software of choice.

- *Metashape photogrammetry software requires a consistent focal length between object and camera lens.
- Fill the frame with the object as much as possible to maximize details/data.

3.3 ***Input images into photogrammetry software:***

1. Gather images into a folder for efficient upload into desired software.
2. Mask if the software supports it, to maximize the processing.
3. The next process is the creation of point clouds. (Point clouds are sets of data in space.)
4. This is where you can clean up any incorrect cameras/point clouds within the software. You are able to reposition any point/camera that was improperly uploaded.

3.4 ***Following alignment, a dense cloud is built:***

- Dense/sparse point
- This creates a wireframe that develops the mesh.
- Mesh is needed to create a texture frame.
- Higher-order of mesh increases detail in specimen
- Depending on your audience, including dimensions can vary from a high school classroom and extensive research. (i.e tooth on a fossil, depending on the quality, the 3D model can be easily measured for dimensions)

3.5 ***Texture:***

- Texture uses data from the top of the triangles to produce the varying surface texture on the object/sample.

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- *Note:* it is unnecessary to have an excessive amount of triangles as this results in excessive data, needing higher processing, or longer download times.*

3.6 ***Saving/Publishing:***

- Depending on the photogrammetry software, you can download the model in different file formats; STL, OBJ, FBX, and COLLADA (most common file formats).
- This link tells you information about file types, etc: [All3dp 2021 Suggested Photogrammetry Software]
- *Sketchfab automatically produces a persistent identifier once the model is uploaded. However, the identifier is at risk when you re-edit the original sample name.*
- Keep all intrinsic sample information with the model when publishing; If previously stored or owned by another group, note the source.
- *images, project, model, info on the sample, etc*

Things to Consider

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- *Think*: Who is my audience? When capturing a sample, will the 3D product be used for extensive research or classroom studies? This consideration can mean the difference between using a higher-quality camera or using a cellphone to capture the images. Maximize resources, and understand what is or isn't necessary for the process.
- *Think*: Will I be able to capture this object? In some cases, a physical sample with a homogenous color, or reflective surface,

Resources

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Case Studies

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- Shellie Luallin is an avocational paleontologist, and SfM expert. Luallin uses Sketchfab to publish her models as well as AGISOFT to create them. Shellie Luallin as Paleogirl in Sketchfab
- Smithsonian Collections 3D Models
- Cretaceous Atlas: Samples of Captured Geological and Non Geological Specimens
- Digital Morphology at the University of Texas
- Unity: A Developmental Platform That Provides a Variety of Photogrammetry Subtopics

Subtopics

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- 6 Brands Implementing 3D Products as a Marketing Strategy
- Preparing Files for 3D Printing
- Structure from Motion Guide UNAVCO

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