DIGITAL MUSEUM OF LEARNING

An initiative of

JACOBS FOUNDATION

PROCESSING GUIDELINES FOR PHOTOGRAMMETRY

Produced by

VIRTUAL CULTURE

BACKGROUND

The Digital Museum of Learning is a global online museum for children and educators. It is an initiative of the Jacobs Foundation. The Digital Museum of Learning partners with museums, collections, and cultural institutions around the world to digitize their artifacts and artworks and bring them to life in interactive stories. Its online exhibitions are carefully curated collections of stories that explore the history and future of learning.

Lacking Standards for Cultural Heritage Digitization

As the Digital Museum of Learning embarked on its journey to digitize cultural heritage, we quickly realized that small and underfunded museums need help digitizing their collections. In addition, museums often rely on proprietary software solutions to digitize collections, which limits interoperability and accessibility for schools. We believe in harnessing the power of cutting-edge computer-aided imaging technologies, interoperability, and open access to digital cultural heritage. Our goal is to efficiently create high-quality, awe-inspiring 3D models and transform them into engaging and interactive experiences accessible to children and schools. In the future, cultural institutions will be able to use virtual and augmented reality technologies to create immersive and interactive experiences of historical sites and artifacts, allowing a global audience to engage with and gain a deeper understanding and appreciation of digitized cultural heritage.

Making Cultural Heritage More Accessible

In collaboration with museum partners and experts worldwide, we are charting a path toward a future where cultural heritage is more accessible to a broader audience, with a focus on schools. The mission of the Digital Museum of Learning is to empower educators and enable children to explore historical artifacts playfully and interactively, fostering a deeper understanding and appreciation of our diverse and shared history.
Anyone with an internet connection can access the digitized artifacts in the Digital Museum of Learning. The stories created around artifacts allow educators to use historical objects for learning activities without the need for a facilitator. This step in democratizing access to cultural heritage is especially important for marginalized communities who may have been historically excluded from participating in the preservation and sharing of their cultural heritage. Traditional methods of preserving and sharing cultural heritage, such as physical museums and archives, are limited by location, cost, and opening hours.

Preserving Cultural Heritage for Future Generations

Many physical artifacts and documents are at risk of deterioration, loss, or destruction due to factors such as natural disasters, human conflict, neglect, or lack of resources. Helping museums digitize these resources ensures that they are preserved in a format that can be easily reproduced and preserved for future generations to access and learn from.
Partner with the Digital Museum of Learning by contributing artifacts and resources. Together we can unlock the rich history and future of learning!

The Guidelines

These guidelines stem from a cooperation between the Digital Museum of Learning, researchers from the Digital Humanities Lab at the University of Basel, and experts from Virtual Culture GmbH. The Digital Humanities Lab at the University of Basel is a center of excellence in computer-aided imaging technologies. Virtual Culture digitizes, implements, and consults cultural heritage institutions and GLAMs (galleries, libraries, archives, and museums).
Together, we created a 3D model of a botanical box from the collection of the Schulmuseum Bern, Switzerland for the Digital Museum of Learning (see: A box full of botanical adventures! https://www.museumoflearning.org). The process was documented in guidelines and accompanying videos. These guidelines describe the basics of close-range photogrammetry, a process used to create 3D models of small to medium-sized artifacts. They consist of two parts:

Part 1) Capturing Guidelines explore the process and necessary equipment to create high-quality images of an artifact (doi: 10.5281/zenodo.7923606)

Part 2) Processing Guidelines describe how to generate a 3D model from these images using image-based modeling software (doi: 10.5281/zenodo.7940422)

The guidelines were produced to facilitate the creation of digital cultural heritage for those who have not yet established a digital workflow in this area, as well as for museum partners and photographers, to help them capture, process, and deliver 3D models. For a more in-depth understanding of the showcase documentation, please refer to the accompanying video recordings for an easier and more accessible walkthrough:

Video 1) 3D Model Stage Preparation - PHOTOGRAMMETRY (doi: 10.5281/zenodo.11259368)
Video 2) 3D Model Capturing - PHOTOGRAMMETRY (doi: 10.5281/zenodo.11259651)
Video 3) 3D Model Processing - PHOTOGRAMMETRY (doi: 10.5281/zenodo.11260493)

1. INTRODUCTION

First Steps
Generating a 3D object using photogrammetry may seem simple at first. However, there are several critical steps in the workflow that are necessary to achieve a good result. The following guidelines will help you make the transition from source images to a 3D model. A high quality 3D model is characterized by its accuracy, precision, and validity. A good set of photographic images is the first requirement for this result.

The 3D Model Capturing Photogrammetry Guidelines (doi: 10.5281/zenodo.7923606) provide a detailed description of all the steps necessary to obtain good image data. Following the instructions in the "Capturing Guidelines for Photogrammetry" will give you an ideal starting point for processing images into a 3D model.

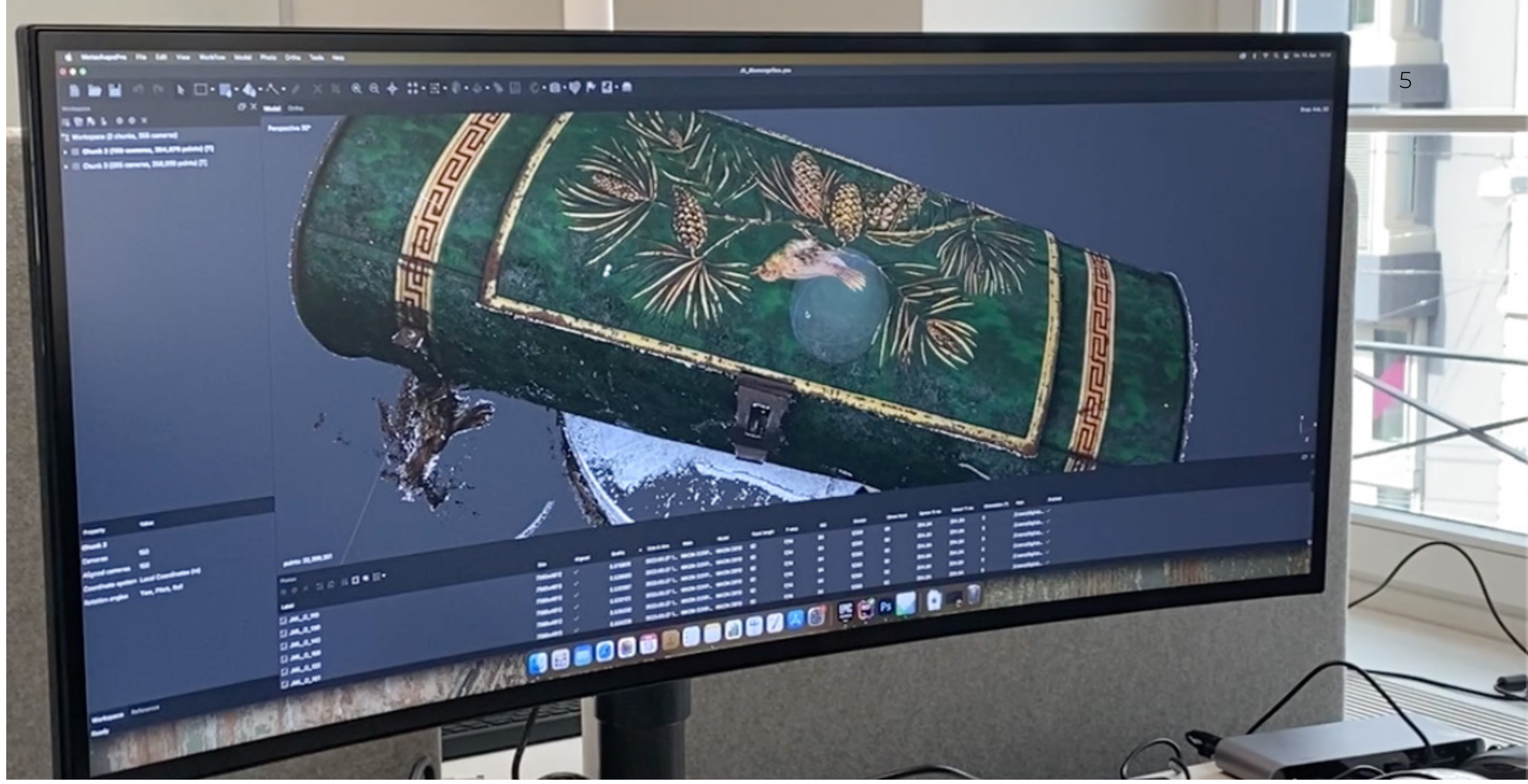
2. PROCESSING EQUIPMENT

2.1 GRAPHICS COMPUTER

Processing a 3D model requires powerful hardware, which is to say a computer or workstation for image or graphics editing, or a high-performance PC like those used for gaming. These specialized machines are designed to handle the demanding requirements of graphics-intensive tasks. Photogrammetry involves processing and analyzing a large amount of visual data to reconstruct 3D models or measurements, making it a computationally intensive process. We recommend using a computer with a robust graphics card, fast processor, plenty of RAM, and a high-resolution display.

WHEN SELECTING THE HARDWARE YOU WANT TO USE FOR PROCESSING, YOU CAN USE THE FOLLOWING RECOMMENDED SPECIFICATIONS AS A GUIDE:

- A multi-core CPU with a high clock speed, such as the Intel Core i7 or AMD Ryzen 7.
- A minimum of 16 GB RAM is recommended, although 32 GB or 64 GB is preferable for larger datasets.
- A high-end graphics processing unit (GPU) with sufficient VRAM (at least 32 GB) is necessary.
- We recommend a solid state drive (SSD) with a capacity of at least 512 GB.

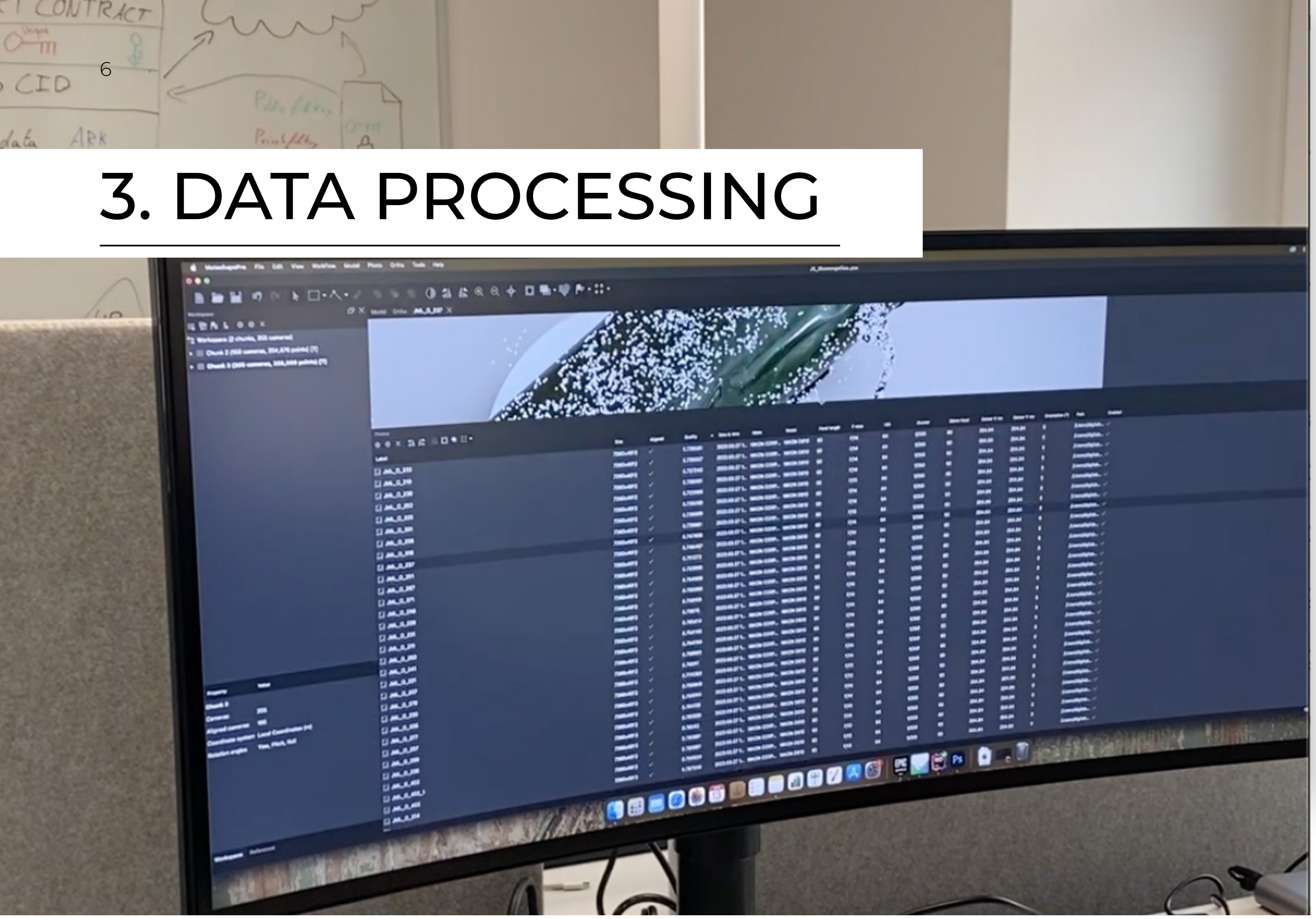


2.2 SOFTWARE

Image-based modeling, more commonly referred to as photogrammetry or structure from motion photogrammetry (SfM), uses highly efficient algorithms (i.e. multi-view stereo, mesh reconstruction, texture synthesis) to create a textured 3D model from imported image files. The software relies primarily on the pixel data of the imported source files. No matter what software you choose, the images you capture will determine the quality of the final result. This means that the quality of the source images plays a significant role in creating a high-quality 3D model using image-based modeling (IBM) software. There are several photogrammetry software packages available. Your choice of software will depend on your specific needs, project requirements, and budget. You may want to try out different software options and evaluate their capabilities, results, and costs to find the best solution for your workflow and objectives. It is worth noting that the process outlined here is based on Agisoft Metashape, a widely accepted industry standard software that has gained considerable recognition in the field for its robustness and efficiency.
The various software solutions available offer a wide range of customizable settings that allow for greater control over the intricate processes involved in creating a detailed and immersive 3D model. In the subsequent part of these guidelines, we will take a closer look at the main steps required to achieve an accurate, error-free result.

SHORT OVERVIEW OF IBM SOFTWARE PACKAGES:

- Agisoft Metashape, formerly known as Agisoft PhotoScan, is widely used to create 3D models and orthomosaics from aerial and terrestrial photographs. Metashape requires a license and the professional version in particular is expensive.
- COLMAP is an open-source photogrammetry software that provides a comprehensive set of tools for the reconstruction, visualization, and analysis of 3D scenes from images.
- Meshroom is a well-known open-source photogrammetry software that uses a node-based approach to processing. It offers a user-friendly interface and employs structure from motion (SfM) and multi-view stereo (MVS) technology.
- Pix4D offers a suite of photogrammetry software specialized for drone mapping and surveying applications. It offers advanced photogrammetric processing capabilities and provides solutions for various industries. The software license is not free; a monthly or yearly subscription is required.
- RealityCapture is known for its quick and efficient photogrammetry processing. It can handle large datasets and provides tools for meshing, texturing, and creating high-quality models. Licensing for RealityCapture is available in two options: either based on a limited number of processing steps or purchased as an unlimited license.



3. DATA PROCESSING

3.1 IMAGE DATA PROCESSING

In photogrammetric processes, the primary source material consists of photographic images. In addition to the bitmap RGB image data, it can be advantageous to have metadata about the acquisition process and the equipment used. This metadata is typically automatically generated by most cameras and can be stored either within the image files or as a separate sidecar file, often in XML format. Although not essential to the 3D workflow, it is recommended to use meaningful filenames for future storage and archiving purposes. The filename itself serves as important meta-information, so it is advisable to choose a distinctive filename that includes details about the artifact, location, and other relevant information.

PROCESS THE IMAGES:

1) If the images were taken in a RAW format such as NEF, CR2, FFF, or DNG, it is worth converting to a standard format such as TIFF.
2) Avoid altering the brightness, contrast, or sharpness of images. Doing so can negatively affect image consistency, which is crucial for proper processing.
3) Ensure that factors such as color balance are consistent across all images.
4) Import the standardized files into the software.

4. MODELING

START THE MODELING PROCESS:

1) Command the software to align images for accurate placement in the model.
2) Start the point cloud calculation by converting the aligned images to 3D points.
3) Create a mesh by connecting points to form a solid structure.
4) Refine the mesh by smoothing out rough edges or irregularities.
5) Texture mesh to improve visual appearance.
6) Export the final model for storage and dissemination.

"A keen eye and meticulous attention to detail are essential throughout the process. Take the time to carefully review and evaluate each step, taking full advantage of the visualization and analysis tools provided by photogrammetry software. By ensuring the accuracy and reliability of your 3D models, you can be confident in their quality and suitability for your intended use. Keep in mind that although some of these processes can be fully automated, they still require a significant time investment."

4.1 ALIGN IMAGES

Once you have imported your images into the photogrammetry software, the first step is to align them. This involves identifying common features in each image and using them to calculate the camera position and orientation for each image. These features can be corners, edges, or key points that can be uniquely identified across different images. The goal is to find reliable and identifiable points in the images that can be used for matching and reconstruction. Once the features are extracted, the algorithm matches the corresponding features across different images. This is an automatic process that involves identifying common or key points in the images and establishing correspondences between them. The matching process can be quite intricate, requiring complex calculations and algorithms to determine the best matches and ensure precise alignment of the images. This process will allow you to identify similarities and patterns, ultimately increasing the accuracy and reliability of the results obtained.

4.2 BUILD THE POINT CLOUD

Once the images are aligned, the software will use information from each image to build a point cloud. Based on the matched feature points, photogrammetry algorithms calculate the depth information or distance to the objects in the scene. This is achieved through triangulation, where the algorithm calculates the 3D position of each point based on the known camera positions and the correspondences. The resulting set of 3D points forms a point cloud that represents the surface geometry of the objects.

4.3 CREATE THE MESH

To create a solid 3D model, the point cloud is often further processed to create a mesh representation. The mesh consists of connected triangles that approximate the shape of the objects in the scene. This involves connecting the points, smoothing the surface, and refining the geometry to create a visually appealing and accurate representation of the object.

4.4 REFINE THE MESH

Depending on the quality of the point cloud and mesh, it may be necessary to refine the mesh to improve its accuracy and smoothness. This can be accomplished using various tools in the photogrammetry software. For example, mesh filtering tools can be used to effectively eliminate any structural noise that may be present. Implementing these tools allows for a reduction in the total number of points within the model, creating a more streamlined representation. In addition, hole-filling applications can be used to seamlessly fill any gaps or holes that may exist within the model, ensuring a complete and flawless result.

4.5 TEXTURE THE MESH

For realistic color and appearance, photogrammetry algorithms project the textures from the original images onto the reconstructed 3D model. This involves mapping the 2D image information onto the 3D surface while taking into account lighting conditions, shading, and texture distortion. The mesh can then be textured using the original images, adding color and detail to the model's surface. In most cases, texture generation is automated. In situations where automated texture mapping is not feasible, it can be done manually. The manual texture generation process demands a considerable amount of manual labor and expertise.

4.6 EXPORT THE MODEL

Once the model is complete, it can be exported in a variety of formats for use in other software packages or for 3D printing. It is important to choose the appropriate format for your intended use, such as OBJ, STL, or FBX. One very popular software solution for photogrammetry visualization is Blender. Blender is a comprehensive open-source 3D creation suite that includes a wide range of functionalities beyond photogrammetry. It is a powerful and versatile software for 3D modeling, animation, rendering, and visual effects.

5. DISSEMINATION

EXPORT THE MODEL FOR DISSEMINATION:

1) Determine an appropriate file format for export.
2) Select the components that will be exported.
3) Verify the quality of the result by opening the file in another program.

5.1 3D PLATFORM

There are dedicated platforms that allow you to upload and host 3D models on the web, providing an easy way to embed and share models. Platforms such as Sketchfab, p3d.in, or Clara.io offer features including model embedding, customization options, and social sharing. The Digital Museum of Learning currently uses Model Viewer. Make sure your 3D model is in a compatible file format, such as .gltf or .glb. These formats are commonly used for 3D models on the web. Please refer to the Model Viewer documentation for detailed information on requirements.

5.2 WEBSITE INTEGRATION

JavaScript libraries such as Three.js, Babylon.js, or A-Frame provide powerful tools for rendering and displaying 3D models directly in a web browser. These libraries allow you to create interactive 3D scenes, apply textures and materials, and enable user interaction with the model using mouse or touch controls.

All of these libraries are based on WebGL (Web Graphics Library). WebGL is a JavaScript API that enables hardware-accelerated rendering of 3D graphics in web browsers. By using WebGL, you can create custom WebGL applications or integrate 3D models into existing web pages for an immersive and interactive experience.

5.3 AUGMENTED REALITY

The advent of WebXR, which enables immersive experiences on the web, allows you to present 3D models in augmented reality directly in web browsers. Frameworks such as AR.js or 8th Wall enable users to view 3D models in the real world through the device's camera, providing interactive and immersive AR experiences on compatible devices.

REFERENCES

SOFTWARE:

Photogrammetry

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https://alicevision.org/#meshroom
https://www.regard3d.org/

Modeling, Texturing, Rendering

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