Digitization of the Virtual Reality Laboratory Through Photogrammetry Tools (SfM)

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***Abstract* – The present paper focuses on generating a digital laboratory model at the department by applying the structure from motion technique. The generated digital model is then utilized to create simulation models for application in virtual and augmented reality environments. Nine different approaches to photogrammetric imaging in the laboratory were tested in the experiment. These approaches involved variations in the number of photographs and scanning positions. The results of the experiment were divided into three categories: unsuitable, which required significant modification; incomplete, which required further modification; and suitable, which was directly usable. Some images were unusable due to the similarity of objects in the scene. Experiments showed that some parts of the laboratory were more appropriate to image separately. It was also found that dark and shiny surfaces of objects presented a problem for the computation of the models. Therefore, it was necessary to use markers or colours to eliminate this problem.**

***Keywords* – Photogrammetry, Meshroom, Blender, Unity, virtual reality, simulation model.**

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1. Introduction

The presented contribution describes a study and an applied experiment focusing on photogrammetric imaging of a laboratory. The experiment includes testing nine different approaches that combine varying numbers of photographs and shooting positions in the laboratory. These approaches were systematically categorized into three groups: inappropriate, requiring significant adjustments; incomplete, requiring additional modifications; and suitable, directly applicable. Some imaging was deemed inappropriate due to the similarity of objects in the scene, leading to the decision to capture certain parts of the laboratory independently. Dark and glossy surfaces of objects posed a challenge, addressed by using markers and colors to solve issues with model computation.

Furthermore, an interactive tour of the laboratory in virtual reality was created using the Unity 3D software and the XR Interaction Toolkit. The laboratory was divided into multiple sections, and textures were subsequently generated from the captured photographs. Interactive elements were added to objects to enable user manipulation. Scene navigation was achieved through teleportation, and interactive objects were marked with corresponding tags. To enhance model computation, glossy surfaces were marked with square tags. Monitors in the laboratory displayed content that minimized irregularities in the resulting models. This approach resulted in the creation of a comprehensive virtual presentation of the laboratory in virtual reality.

Photogrammetry is a method of imaging and measuring that makes it possible to obtain accurate geographic information about real objects and environments from images or photographs. Through the application of photogrammetry tools, the following options are possible:

- 3D Modelling: It is possible to create three-dimensional models of objects and terrains using photogrammetry. These models have precise dimensional data and can be created from different viewing angles and perspectives.

- Precise measurements: Photogrammetry allows precise measurements of distances, heights, depths and dimensions of objects. These measurements are important in numerous industries, e.g. surveying, construction, and archaeology.
- Mapping and cartographic applications: Thanks to photogrammetry, it is possible to create accurate maps and orthophoto maps used in geographic information systems (GIS) and urban planning.
- Terrain analysis and environment change: Photogrammetry monitors terrain and environment change, which is important for environmental and geomorphological studies.
- Accident scene reconstruction: When investigating traffic accidents or criminal cases, photogrammetry can help reconstruct scenes and determine the causes and circumstances of events.
- Virtual reality and simulations: Photogrammetric models are often used in virtual reality and computer simulations to create realistic visual environments.
- Archaeology and Cultural Heritage: Photogrammetry assists archaeologists and conservators in documenting and preserving historic and cultural sites.
- Forest area management and surveys: In forestry, photogrammetry is used for monitoring the state of the forest and planning its management.

The above approaches provide photogrammetry with important information and tools for many industries involved in environment analysis and object measurement. Currently, photogrammetry is moving towards integrating or embedding photogrammetric components into application-oriented hybrid systems. This is the process of linking to 3D CAD systems, databases and information systems, quality analysis and production management systems, navigation systems for autonomous robots and vehicles, 3D visualization systems, web applications, 3D animation and virtual reality. Other trends are the increasing use of methods from computer vision, such as projective geometry or pattern recognition, for fast solutions that do not require high accuracy. Virtual reality (VR) is the term used to describe an interactive computer system that creates the illusion of physical presence in a computer-generated three-dimensional environment. Users are immersed in this environment and can manipulate objects or perform actions. One or more persons can explore and interact with the virtual environment.

Using a combination of virtual reality technology and digitization through photogrammetry facilitates the reconstruction of real objects and accelerates the creation of space for virtual environments.

Recent developments have brought about several changes in communication, and the need for physical presence is gradually being replaced by virtual reality. These changes have affected the engineering industry, business dealings, entertainment industry, education and other industries. Businesses have gradually started digitizing their facilities and are preparing to utilize them practically. Education is suitable for such digitization and subsequent rapid use for teaching or presentation of school premises.

2. Photogrammetry

Photogrammetry represents a 3D measurement technique that uses centre projection as its basic mathematical model. Its history is almost as long as the history of photography, and for the first 50 years, photogrammetry was used for close-up and architectural measurements. In the 1830s, experimentation with measurement from perspective views began. Photogrammetry experienced significant advances during the First World War. It was used to create accurate maps of battlefields and to measure distances between different points. After the First World War, photogrammetry became an important mapping and precision measurement tool in several industries, including surveying, civil engineering, and aerial applications. The 1950s witnessed the early days of analytical photogrammetry. This decade's expanding use of digital electronic computers shifted the interest from the prevailing analogue methods to a purely analytical or numerical approach to photogrammetry. Since the mid-1980s, the use of optoelectronic image sensors has increased significantly. Advanced computer technology has enabled the processing of digital images, particularly for automatic recognition and measurement of image features, including the determination of object surfaces. [1]

Among the recently widespread software tools that implement techniques and algorithms for reconstructing a 3D model from a photograph is computer vision. Computer vision is a mathematical technique used to recover the three-dimensional shape and appearance of objects from images. Computer vision originated in the 1970s, intending to equip robots with visual perception. The evolution of computer vision technology is illustrated in Figure 1. [2].

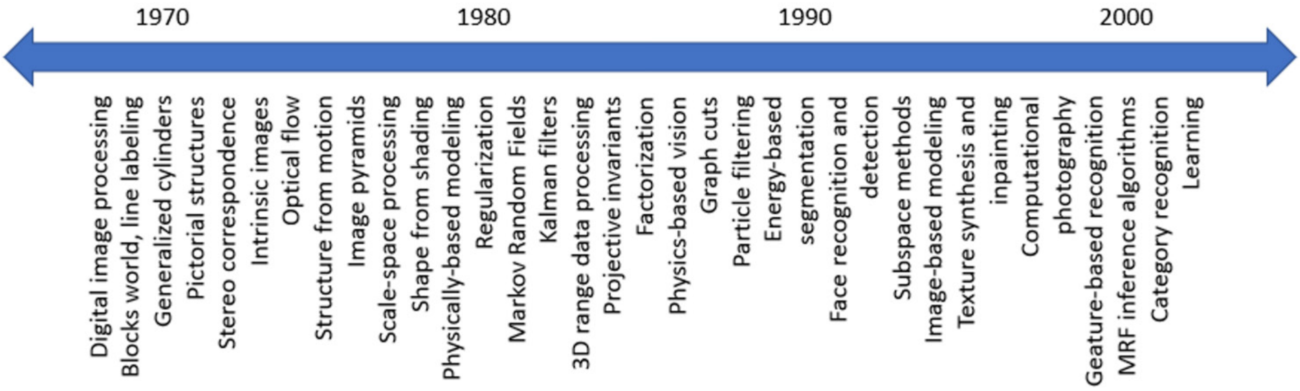


Figure 1. Timeline of the most important technologies in computer vision [2]

Although there is no clearly defined range of digitized object size and accuracy, photogrammetry can be used to digitize objects in the size range of 0.2 to 200 m with an accuracy of up to 0.1 mm for close objects and about 10 mm for larger objects. Depending on the field of application, industrial photogrammetry can be defined as utilized in applications in a manufacturing environment. According to the availability of digitization results, photogrammetry can be divided into offline, online, and real-time photogrammetry. In offline photogrammetry, image capture and processing are performed in separate phases. In online photogrammetry, image acquisition and processing are performed simultaneously, and the result is quickly available. In real-time photogrammetry, image acquisition and processing are performed within a specified time range. Photogrammetric techniques can be divided according to the camera position and distance from the object as follows [1]:

- satellite photogrammetry (imaging from an altitude of approx. 200 km),
- aerial photogrammetry (imaging from altitudes above 300 m),
- UAV photogrammetry (drone photography from an altitude of approx. 100 m),
- terrestrial photogrammetry (imaging from a specific location on the Earth's surface),
- photogrammetry of nearby objects (sensing at distances up to 200 m),
- underwater photogrammetry (sensing underwater or through the water),
- macro photogrammetry (imaging using macro optical technology)
- and mobile mapping (data acquisition from moving vehicles from a distance of up to 100 m).

2.1. The Principle of Photogrammetry

In the photogrammetric process, information about the shape and position of the object is obtained and determined by reconstructing a bundle of lines within which a point P' and a perspective centre point O' are determined for each camera and each image frame, which are used to define the spatial orientation of the lines intersecting a common point on the object P (Fig. 2). Based on this principle, the orientation of the camera in 3D space can be determined for each bundle of line images. Based on the intersection of at least two spatially disparate lines from the image frames, a point on the object can be defined in 3D space. The internal orientation parameters describe the internal geometric model of the camera and need to be defined and calibrated for each camera separately. In the production of functional cameras, the camera's internal orientation parameters are almost always defined and calibrated in advance during the manufacturing process, and photogrammetric software can, in most cases, define these parameters automatically. The camera's exterior orientation parameters define the position and orientation of the camera in the Global Coordinate System (GCS) space. The exterior orientation parameters are indirectly computed and are defined by the coordinate of the centre point of the perspective within the GCS and the Image Coordinate System (ICS). For each image frame, a bundle of straight lines is defined by image points and a central point of perspective at which information is captured simultaneously. By joining points of the object within the space, a point cloud is obtained, while other data, such as information about the colour and texture of the object, can also be captured [1].

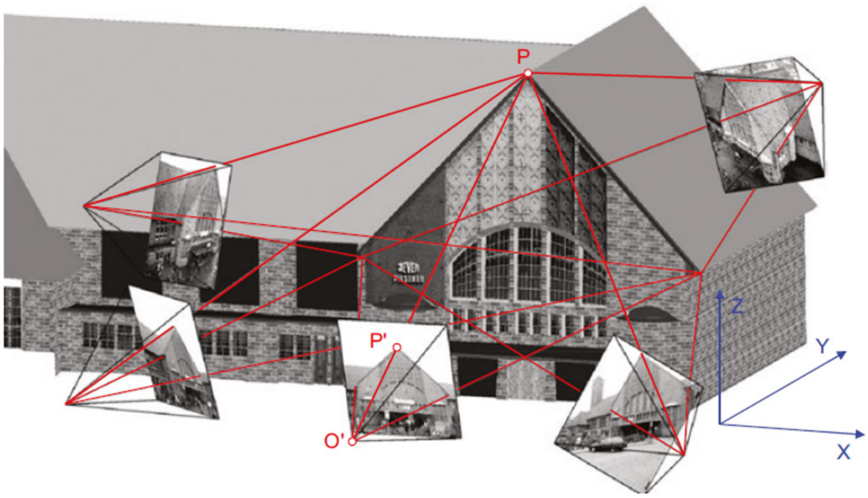


Figure 2. The basic principles of photogrammetry [1]

Despite some exceptions, it can be argued that the photogrammetric process is now mainly carried out by digital cameras using digital image file processing methods. Systems can be developed to perform the photogrammetric process automatically, without the need for manual data capture and processing, as required.

As mentioned earlier, the photogrammetry process can be divided into offline and online. Offline photogrammetry uses a single camera whereby all images must first be captured by the camera and then processed. Online photogrammetry uses at least two cameras to digitize the surface continuously and immediately generate output data. If it is possible to fix the data acquisition time to a certain period, such a process can be defined as real-time photogrammetry (RTP). The photogrammetric digitization process can be divided into stages - data acquisition, pre-processing, post-processing, measurement, and analysis. The main output of the photogrammetric process of object digitization can be considered as 3D coordinate points of the object surface-point cloud derived from the acquired images. Other output data can be derived from them, e.g. polygons, lengths, surface areas, analysis data comparing the acquired data with a nominal model and other surface information. Figure 3 shows a schematic of the photogrammetry process [3].

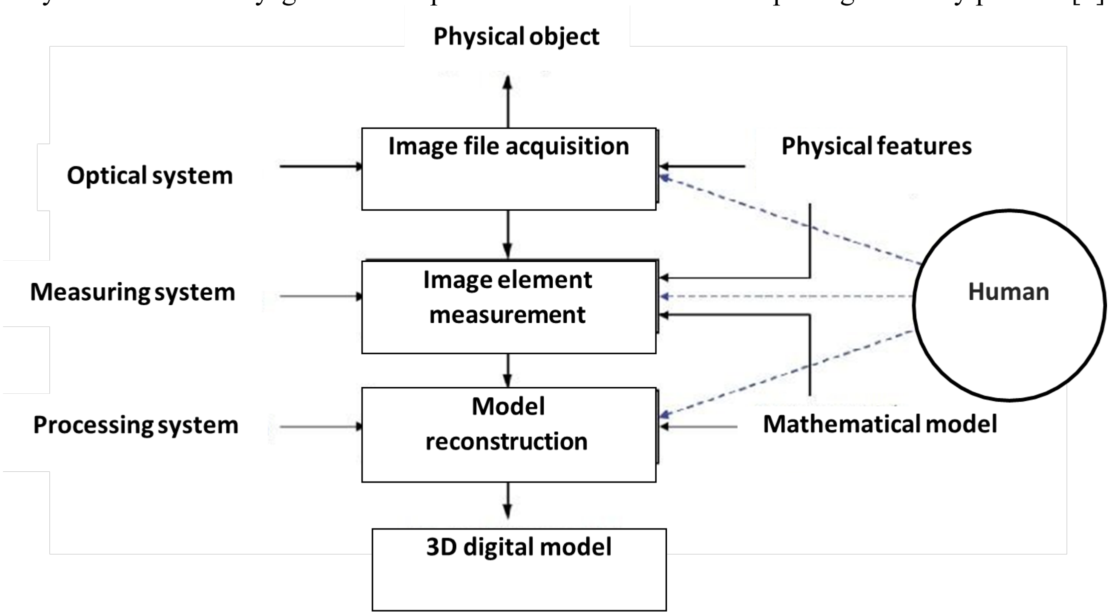


Figure 3. Photogrammetric process from object to model [4]

Photogrammetry involves methods of measurement based on image files and their interpretation for obtaining the surface, shape, and location of a physical object from one or more photographs of that object. To digitize objects using photogrammetry techniques, it is necessary to know the exact location of the cameras for the calculations [4].

2.2. Structure from Motion

Structure from motion is the process of estimating 3D object structure and camera motion from 2D image sequences. Photogrammetry, as a technique for digitizing physical objects, is applicable provided that the object can be photographed and the camera can be moved within the space. Primarily, photogrammetry is intended for the digitization of physical objects for the acquisition of 3D surface data (close-range photogrammetry), or it can be used for the creation of graphical media (aerial photogrammetry), such as geographical maps. Physical model reconstruction based on image-based calculations uses the creation of point marks on an object according to the image shapes, brightness, and colour distribution in the images. At the beginning of reconstructing physical objects by photogrammetry, it is necessary to establish a method for interpreting and measuring the images that make it possible to create these point marks. This requires measuring and sensing equipment with geometric and optical quality characteristics. The object can be reconstructed thanks to this measurement and mathematical transformation between the images and the object space. The quality of the reconstructed model and the correspondence with the image template are related to the physical characteristics of the object and environment to be imaged, the mathematical model chosen for the calculation, and the experience and skills of the person involved in the photogrammetric process. [4]

An image sequence containing the object or scene is acquired at the beginning of the photogrammetric process. The observed scene and the camera movement are the same so that the different elements of the scene will be present in more than one frame. These features are extracted and tracked through the captured frames. To compute the SfM, the multi-view geometry is applied to these features, the external camera parameters are estimated, and in the last step, the 3D Ssructure of these points is obtained [4], [5].

2.3. Overview of the Papers Published in the Field of the Issue Addressed

Authors Abdul Hannan Qureshi, Wesam Salah Alaloul, *et al.* [6] describe the results of a study focusing on the development methodology for evaluating photogrammetry tools. The evaluation process consisted of three steps, including metadata creation, visual inspection, comparison with the ground truth model, and subsequent comparison with the merged average point clouds model.

This research also proposes a potential avenue for the development of photogrammetry. During the study, a hypothesis was formulated during the experimentation phase. The null hypothesis stated, "There is no need for scale-based calibration in the 3D point cloud model generated from images with the same working distance" [6].

Fraley *et al.* explore alternative methods of generating 3D solid models without using expensive 3D scanning technologies [7]. Their case studies comparing two software tools confirmed satisfactory final results in terms of model quality when adhering to the required procedures for accurate data capture and subsequent processing of acquired data [7].

Reljić *et al.* evaluate the quality of 3D models generated from the same input data file using selected photogrammetry software tools [8]. They assessed the characteristics of these applications in terms of the resolution of the resulting model, final file size, reconstruction time, and visual qualitative analysis [8].

A specific implementation of a high-performance photogrammetric service is presented in [9]. Although the service is currently based on a specific software package (Agisoft PhotoScan), the implemented system architecture is designed around a general photogrammetric process that can be easily adapted to use other photogrammetry tools. The paper also describes a study measuring the relative impacts of file size, software quality settings, and processing cluster size [9].

Fawzy [10] describes a study focusing on the accuracy of a digital technique using computer photogrammetric software called Fotomodeler. This software relies primarily on two mathematical theories—direct linear transformation (DLT) and scale-invariant feature transform (SIFT)—for quantifying measurements. The aim of the presented work is to provide an explanation of this software technology. Several laboratory experiments were conducted to assess the maximum possible accuracy of the software and verify whether the software meets proposed standard values. [10]

The possibilities of applying photogrammetry in the field of augmented reality are discussed in [11]. The authors describe a proposed methodology aimed at users with low digital literacy, complemented by a series of recommendations that enable the creation of three-dimensional models using photogrammetry in lightweight, affordable software applications [11].

3. Processing Phase, from Object Sensing to the Modified 3D Laboratory Model - Experimental Part

In order to create a simulation laboratory model, photographs were generated on two devices, and then 3D models were constructed using Meshroom software. Darktable was utilized to edit the photographs if necessary, and the models were edited in the Blender environment. The resulting virtual tour was designed in the Unity 3D graphics engine. The VR equipment required for educational purposes comprises a head-mounted display (HMD) and a position and orientation tracking system. With HDM displays, the illusion of depth is created by having each display show the virtual environment from a different viewpoint. The display tracks the user's head movements and changes the view of the virtual environment accordingly.

3.1. Meshroom

Meshroom is a free, open-source software that can create 3D reconstructions using AliceVision's computer vision and photogrammetric framework. AliceVision provides algorithms for 3D reconstruction and camera observation. AliceVision aims to provide a powerful software base with state-of-the-art computer vision algorithms that can be tested, analyzed, and reused. The advantage of this environment is the ease of use [12].
Meshroom focuses on two possible applications.

- Simple extraction of a 3D model from a dataset with minimal user intervention.
- Editable solution for advanced users.

The software tool Meshroom was chosen due to its application capabilities, performance, and efficiency, despite being an open system. It leverages modern computer vision algorithms and techniques for the effective processing of photographs and the creation of accurate 3D reconstructions. Meshroom supports parallel processing, allowing the utilization of the power of modern multi-core and parallel systems. This can significantly accelerate the process of creating 3D reconstructions, especially with large datasets. The software is designed with an emphasis on a user-friendly interface, meaning that even users without specialized knowledge in photogrammetry and computer vision can effectively work with it. The selection and application of Meshroom were influenced by the fact that the software environment utilizes a graphical approach to defining and visualizing the workflow. It supports the assembly and customization of the workflow through an integrated graphical user interface.

AliceVision is a framework utilizing a data stream from initial editing to the final rendering of a 3D model. The AliceVision photogrammetric chain contains [15]:

- Extraction of natural features,
- comparison of images,
- comparison of properties,
- structure from movement,
- depth map estimation,
- networking,
- textures,
- localization.

3.2. Creating Photos

Photo quality is the most important and challenging part of the photogrammetry process.

Table 1. Basic settings of the photogrammetry equipment

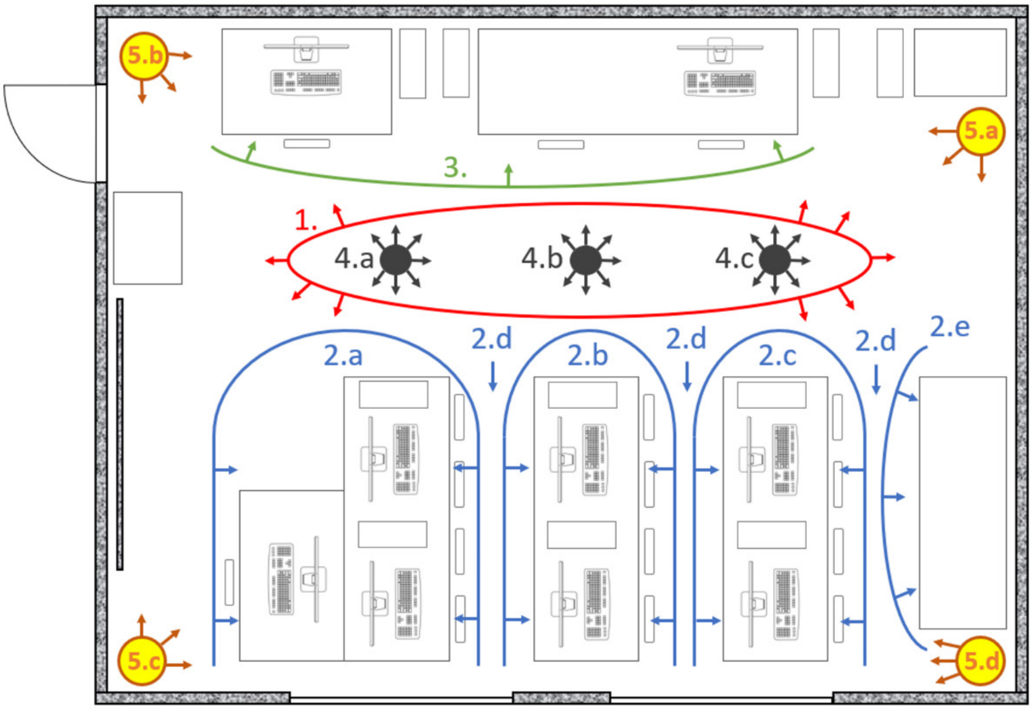
Settings	**Sony ILCM-7M2**	**Xiaomi Mi 9T Pro**	**Feature setting**
Shutter speed [seconds]	1/40	1/30	A high shutter speed is needed to reduce or prevent motion blur.
Focal length [mm]	28	4.77	In photogrammetry, where precision and details are crucial, it can be beneficial to use a lens with a normal focal length, which provides good depth of field and preserves details across the entire scene.
ISO	200	200	Low ISO is used to reduce noise.
Resolution [pixels]	6000 x 3376	4000 x 3000	The size of the resolution is important to preserve sufficient detail.
Aperture	f/7.1	f/9	For most photogrammetric projects, it is often recommended to choose intermediate values of f-numbers. It is a compromise setting that provides sufficient depth of field while minimizing issues associated with too large or too small an aperture.

Basic photographic conditions for photogrammetry are as follows [13]:

- The scene/object should be well-lit,
- Avoiding shadows, reflections, and transparent objects,
- Imaging in diffused or indirect lighting,
- Not using the in-camera flash,
- Not changing the focal length/zoom during imaging,
- Imaging the object from all angles,
- Avoiding moving objects in the background,
- Avoiding blurred images,
- The advantage is taking more photos

Two devices (Xiaomi Mi 9T Pro and Sony ILCM-7M2) were used to take the photos. The room which was digitized using photogrammetry had dimensions of 6 x 6.5 meters.

In the first attempt to image photographs of the room, a random image formation was performed. Each object was photographed in the room from each side, and the individual images were spaced no more than 10 degrees apart. The result of such imaging was insufficient due to the similarity of some objects, such as the desks intended for the students, of which there were six in the laboratory. The resulting scene contained a poorly determined position of some tables and inappropriate positioning, e.g. behind one of the laboratory's walls. After analyzing this experiment, it was desirable to determine several positions for room scanning, as shown in Fig. 4. The most suitable solution was to scan from five main positions, which, for clarity, was convenient to divide into further subgroups. The first position was between the student desks and the VR desk. The second position for scanning was composed of four parts, where individual desks were scanned in parts a, b, c. Part d imaged the space between them, and part e the cupboard at the end of the room. In the third position, two desks were imaged for VR. A room of three points was designed for position four, in the same position as the first part was imaged. The last set of photographs was taken from the corners of the laboratory.



Sequence number	Number of photos
1.	270
2.a	59
2.b	33
2.c	57
2.d	39
2.e	30
3.	256
4.a	196
4.b	175
4.c	136
5.a	46
5.b	40
5.c	32
5.d	64

Figure 4. View of the virtual reality laboratory

The most problematic part of processing photos for photogrammetry was the part with the workbenches. Their similarity made it impossible for Meshroom to calculate a proper 3D scan of the room. The solution was to process photos of only half of the room where the VR workbenches were located and photograph the rest section by section.

3.3. Image Processing Meshroom

Meshroom offers basic settings that are sufficient for photo processing. Fig. 5 shows the basic settings in the graphics editor. For the better rendering of textures, the settings have been changed by adding the PrepareDenseScene2, ,nd Publish windows, which are shown in Fig. 6.

Meshroom was designed to easily extract a 3D model from multiple images with minimal user intervention and provides a solution for advanced users that can be modified to suit their technical needs. Meshroom includes a database of camera sensors to determine internal camera parameters. If images are missing metadata or were taken by a device not recognized by the program, a warning will be displayed next to the image explaining the problem. The photogrammetry process will continue even without camera sensor information, which may negatively affect the resulting 3D scan quality. If it is desired to complete the sensor database, it is necessary to find the camera sensors file and open it, e.g. in Notepad. Information such as manufacturer, device name and sensor size are added (e.g. Xiaomi; Mi 9T Pro;4.77; devicespecifications). A green circle will be displayed next to the images if the device information is available in the database. Next, it is possible to start processing the images by clicking the start button, which is located at the top. However, it seems to be a more convenient procedure to calculate the individual steps sequentially.

CameraInit

CameraInit reads image metadata sensor information and generates viewpoints.sfm and cameraInit.sfm. It can combine multiple cameras and focal lengths. CameraInit creates groups of internal features based on image metadata [12].

FeatureExtraction

This step aims to extract characteristic groups of pixels that are somewhat invariant to changing camera viewpoints during image acquisition. An object in the scene should have similar feature descriptions in all images. The Scale-Invariant Feature Transform (SIFT) algorithm is the most well-known feature detection method. Its goal is to extract and compare distinctive image features regardless of rotation, displacement, and scale [14].

ImageMatching

In this step, it is determined which images make sense to link to each other. This part aims to find images that look into the same areas of the scene [12].

FeatureMatching

This is a comparison of all features between each pair of images. First, a photometric match is performed between a set of descriptors from the 2 input images. A list of matching features in image B is obtained for each feature in image A. The space of descriptors is not linear and well defined, so for each feature descriptor in the first image, the 2 closest descriptors are searched, and a relative threshold is used between them. This provides a list of suitable features based only on the photometric criterion [15].

StructureFromMotion (SfM)

The task is to understand the geometric relationship between the input images and calculate the 3D points with the position (location and orientation) and internal calibration of all cameras. First, all feature matches between pairs of images are combined into points in space visible from multiple cameras. Then, an algorithm is used to select the best initial pair of images, from which their base matrix is computed, and the position of the coordinate system is determined. If the position of the first 2 cameras is known, it is possible to triangulate the 2D features into 3D points [16].

PrepareDenseScene

This step restores the image distortion and generates the EXR image settings. Using ImagesFolders, user can overwrite the input images and do texturing with different images [17].

DepthMap

The task is to retrieve the depth value of each pixel for all cameras that have been resolved using SfM [18].

DepthMapFilter

The DepthMapFilter step enforces the consistency of the depth map [15].

Meshing

This step aims to create a geometric surface representation of the scene. The result is a usable 3D model that does not yet contain a texture. In its settings, it is possible to crop the scene using a bounding box and calculate only the object to be digitized without its surroundings. For faster calculation without changing the resulting mesh quality, the value of the maximum number of depth map connection points has been changed to 1,000,000 [15].

MeshFiltering

MeshFiltering filters out undesired elements of the network settings [15].

Texturing

Texturing creates a UV map, which means projecting a 2D image onto the surface of a 3D model. In the settings, user can change the size of the texture side (Texture Side), the texture downscale value (Texture Downscale), its format (png., jpg., tiff., exr.), the unwrapping method (basic, LSCM, ABF) and the option to use the fill holes function [1].

Publish

A copy of the input files is placed in the output folder. It can save an SfM, Mesh, or texture model to a specific folder [1].

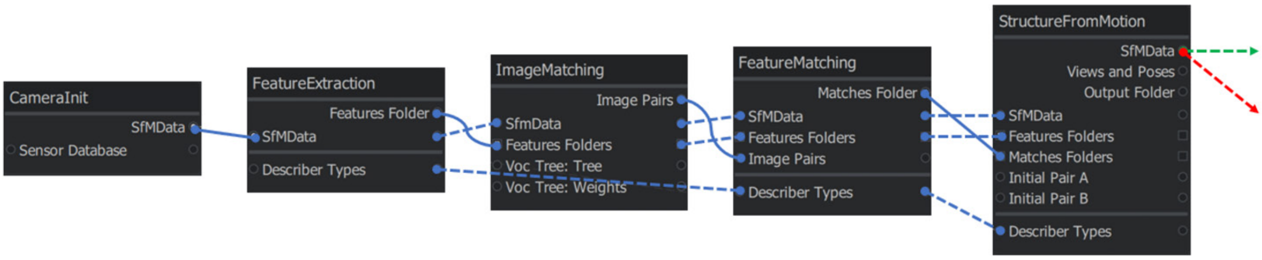


Figure 5. Basic Meshroom settings

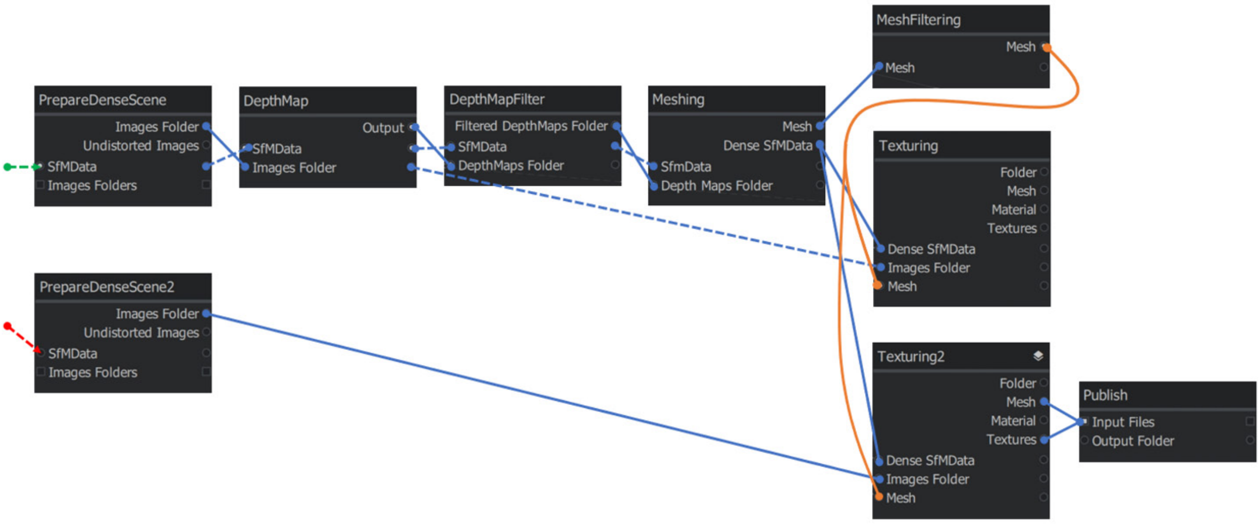


Figure 6. Meshroom settings with added texture

Table 2 lists the different image combinations according to Fig. 4 and contains the number of processed images, processing time, size of the final models and the suitability of each solution.

Table 2. Processing room images in Meshroom

Attempt Number	Combinations	Number of Image	Processed by Images	Time Processing [min]	Size in Mb	Suitability solutions
1.	Random	546	441	305	159	Unsuitable
2.	1	270	270	245	130	Incomplete
3.	1+2d	309	282	255	45	Unsuitable
4.	1+2a,b,c,e+3	675	643	370	120	Incomplete
5.	2a,b,c,e	218	196	210	39	Incomplete
6.	3	256	256	230	67	Suitable
7.	4a,b,c	507	485	310	83	Incomplete
8.	4a,b,c+5a,b,c,d	689	605	362	105	Unsuitable
9.	All	1433	1375	625	440	Unsuitable

Nine variants of the laboratory imaging were tested. The individual scans differed in the number of photographs and the change in the position of the photographs taken. Shoot 1 contained photographs taken randomly, without the application of planned positions. Shoots 2 - 8 contained photographs taken according to the intended positions, and shoot 9 consisted of processing all photographs except those obtained in the first case (random photographs).

The suitability of each solution is divided into three groups: Unsuitable - the resulting model was not suitable, incomplete - the resulting model needed additional modifications, Suitable - the resulting model did not need much modification and could be used. The unsuitability of some experiments was due to the similarity of objects in the scene (workbenches, cabinets).

Through experimentation, it was found that this type of laboratory is unsuitable to be imaged using photogrammetry, and it is better to divide the model into several parts. Fig. 7 shows the virtual reality workbench model created in Sensing 3. For the other parts of the room, scan no. 4 was used. It was necessary to capture each object separately for the remaining parts of the room (such as the transparent display, the projector, the VR glasses, etc.). Through experimentation, it was found that dark parts and shiny surfaces of objects are challenging for the model computation, and dents or voids are created in these areas. The solution is to glue markers on the objects or to cover the shiny surface with paint.

Figure 7. Final scene of area 3 of the laboratory (virtual reality workbenches)

Fig. 8 compares the scanned projector using a Sony ILCM-7M2 camera and Xiaomi Mi 9T Pro smartphone. Sometimes, the difference in color between two photographs can be caused by varying ISO settings, but the influence of ISO on color is typically not a direct consequence of the ISO value. Instead, it is more related to the lighting conditions during capture and the camera sensor's response. Both models are suitable for use.

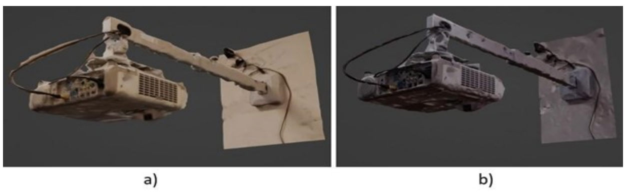


Figure 8. Comparison of scanned projector using a) Sony ILCM-7M2, b) Xiaomi Mi 9T Pro

3.4. Blender

Blender is a 3D computer graphics modelling and animation program. The program provides all the tools to create models and scenes from which still images or animated movies can be created.

This program was used to additionally crop small objects and fill in gaps for incomplete models for glossy and dark surfaces, respectively, as shown in Figure 9. For the models of the different room parts, features were used to simplify and reduce their size for better stability and frame rate of the final application.

Figure 9. Cropped projector model in Blender a) before modification b) after modification.

4. Creating an Interactive Virtual Reality Tour of the Laboratory

The final application was created in the Unity 3D engine, which can be downloaded for free from the publisher's official website. The XR toolkit called XR Interaction Toolkit was used to create the virtual reality. As the scan of the room was divided into several parts, the floor and walls of the laboratory were created in Unity by customizing simple cubes into the desired shape. Already captured photos were used to create the textures and cropped to give the impression of uniformity. The XR Grab Interactable component was added to the objects (goggles for VR, tablet for RR, projector, etc.) that were required to manipulate the controller so that the application would be interactive for the user. Movement around the scene was achieved by teleporting with the controllers, utilizing the Locomotion System and Teleportation Provider scripts. Each interactive object is indicated by a marker placed underneath it. When approaching an interactive object, a text box is displayed describing its features.

Figure 10. View of the laboratory in the final application from the back of the room

Figure 11. View of the laboratory in the final application from the front of the room

Fig. 10 and Fig. 11 show a view of the laboratory in the final application, where hints of movement and equipment on the different tables are visible. The computer cabinets, which had shiny parts and black surfaces, were marked with square markers to calculate the model better using photogrammetry. The screens on the monitors also caused problems in the results, so they had to be switched on during the photographs with the appropriate content displayed that did not cause unevenness and gaps in the resulting model.

5. Discussion

Various issues and challenges can arise in applying photogrammetry, which should be considered when planning and implementing projects. The quality of input imagery is a key factor for the accuracy of photogrammetric modelling. Problems such as blurred images, insufficient overlapping or difficult-to-discern point features can lead to inaccurate results. Proper calibration of cameras is also an important process, which is essential for correctly measuring distances and angles between points. Calibration errors can affect the accuracy of the final models. If the object or camera moves during the acquisition, this can also lead to inaccuracies in the model. Camera stabilization and motion control are, therefore, of paramount importance. The photogrammetric process can be time-consuming and require computational power and sufficient resources, especially when processing large amounts of data.

From the perspective of comparing the devices used to capture images for photogrammetry, it is possible to highlight their distinct characteristics. Digital cameras with interchangeable lenses, such as the Sony ILCM-7M2, excel in their ability to provide better sensor quality and greater control over settings, making them ideal for professional or detailed applications in photogrammetry. On the other hand, smartphones, like the Xiaomi Mi 9T Pro, are suitable for quick and mobile photography due to their compactness and straightforward operation. Smartphones often come with various camera modes and software features that can facilitate photography. In contrast, digital cameras typically offer a broader range of manual settings, including aperture, exposure time, and ISO sensitivity, which can be advantageous, especially in the context of photogrammetry.

It is important to carefully review and plan photogrammetric projects with these issues and challenges in mind and ensure that measures are taken to minimize their impact on the resulting imagery.

6. Conclusion

In the experiment conducted and described herein, nine different approaches to photogrammetric imaging of the laboratory were tested with different combinations of the number of photographs and imaging positions. These approaches were divided into three categories: inappropriate, requiring significant adjustments; incomplete, requiring additional adjustments; and appropriate, which were directly usable. Some of the images were inappropriate due to the similarity of objects in the scene, and therefore, it was better to image some parts of the laboratory separately. The dark and shiny surfaces of the objects presented a challenge for model computation, which was addressed using markers and colour. An interactive virtual reality tour of the laboratory was then created in Unity 3D using the XR Interaction Toolkit. The laboratory was divided into multiple sections, and then textures were generated from the captured photographs. Interactive elements were added to the desired objects for users to manipulate. Movement around the scene was accomplished through teleportation, and interactive objects were marked with signs. Shiny surfaces were marked with square markers for better computation of the models. Content was displayed on monitors in the laboratory to minimize unevenness in the resulting models. This procedure created a comprehensive virtual presentation of the laboratory in virtual reality. Photogrammetry is an important tool for VR creators to create accurate and realistic 3D models from the real world and integrate them into virtual environments. It allows the creation of 3D models of real-world objects and environments from a series of 2D photographs. These models can then be imported into VR environments. This is useful, for example, when creating virtual replicas of real rooms, buildings, or artifacts for museums and galleries as part of VR tours. Photogrammetry can be utilized to create realistic environments for training and simulations in various industries, from medical training to aviation. These environments allow for hands-on training without the risk of real injuries or loss.

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