



Data Article

Datasets of captured images of three different devices for photogrammetry calculation comparison and integration into a laserscan point cloud of a built environment

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ABSTRACT

The presented data article aims to provide the whole dataset obtained during an experiment of updating laser scan point clouds with photogrammetry meshes. In this context, the data quality and calculation time of photogrammetry models from different recording devices and different software solutions were compared. It was investigated whether photos from smartphones are also appropriate for updating point clouds by using photogrammetry in a factory environment. The photos of a technical installation were taken in 08:30 min with these three devices: Nikon D810 with Sigma art 24 mm, iPhone 6 and iPhone XS. With each of the mentioned devices, three datasets have been created to provide enough data for the comparisons. One dataset (photos in .TIFF) of the iPhone XS is provided. The results of the datasets are used for a photogrammetry mesh quality comparison and a calculation time comparison. For the mesh quality comparison, visual qualitative inspections were performed on the models and the results were compared. Furthermore, all settings in the RealityCapture BETA 1.0.3.9696 ppi and Meshroom 2019 2.0 software are provided. A comparison of the quality of the

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photogrammetric 3D meshes was performed by comparing the rendering results. The dataset of the iPhone XS can be used to compare further photogrammetry software or single algorithms. Besides the images, the initial point cloud of the laser scanner is provided. Also included is the combined file which consists of the laser scan point cloud and the photogrammetry mesh of the end of the experiment.

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Specifications Table

| | |
|--------------------------------|--|
| Subject | Civil and Structural Engineering |
| Specific subject area | Recording time and quality comparison of photogrammetry meshes |
| Type of data | Table Image Chart Point cloud Rendering |
| How data were acquired | Data were obtained from camera recordings, laser scans Hardware: Nikon D810 (Lens: Sigma Art 24mm F1.4 DG HSM), iPhone XS, iPhone 6, FARO FOCUS S 350, Computer: Intel® Core™ i7-6700 CPU @ 3.40GHz 3.31 GHz, 32 GB RAM, NVIDIA GeForce GTX980 Ti Software: Reality Capture BETA 1.0.3.9696 ppi, Meshroom 2019 2.0 |
| Data format | Raw, .PNG, .TIFF, .E57, .XLSX Analyzed |
| Parameters for data collection | All calculations were performed on the same PC with different photogrammetry software. The settings in the photogrammetry software are documented in the provided tables. |
| Description of data collection | The photos were taken with a smartphone. An app was used to keep the photo settings for all photos. The calculation times were taken from the log data of the respective software. All calculations were performed on the same PC. |
| Data source location | Institution: University of Stuttgart City/Town/Region: Stuttgart Country: Germany |
| Data accessibility | Repository name: Mendeley Data Data identification number: 10.17632/vfz5pz4n8k.7 Direct URL to data: https://data.mendeley.com/datasets/vfz5pz4n8k/7 |
| Related research article | Hellmuth, R., Wehner, F., Giannakidis A., Approach for an Update Method for Digital Factory Models, Procedia CIRP CMS, 93C, pp. 278-283 Doi: 10.1016/j.procir.2020.03.042 |

Value of the Data

- The data provides the input data and parameters for a comparison of photogrammetry results of different devices and software.
- Researchers conducting evaluation of photogrammetry software or recording devices can use the information about parameters to run similar tests. Researchers also can compare their results with the results shown.
- Photogrammetry results of future smartphone devices can be compared to this data set. Also results of different photogrammetry software can be compared.
- The provided data documents the comparison of the devices and the software. All relevant settings in the software used are displayed. Furthermore, the comparison can be extended based on the data provided.

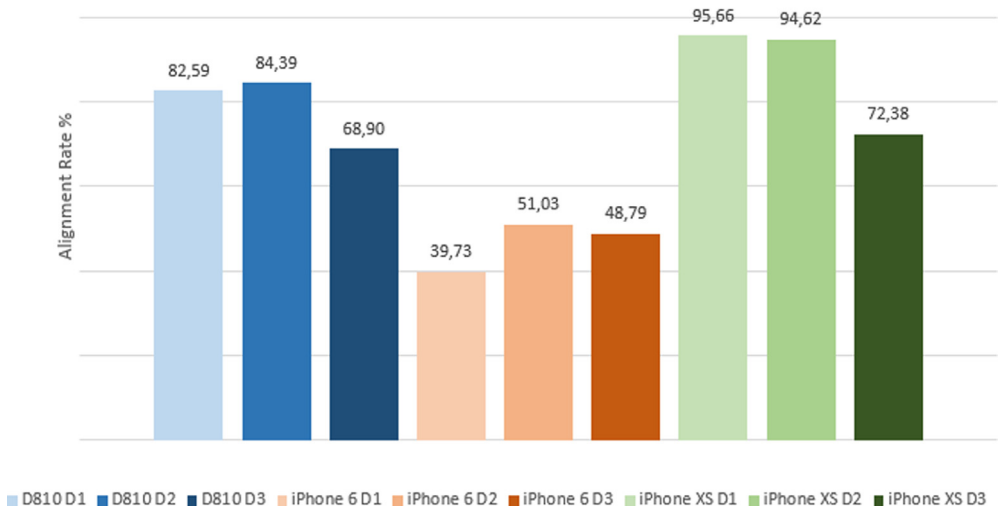


Fig. 1. Alignment-Rate without Control Points (RC).

1. Data Description

All illustrations that are presented and mentioned here can also be found at: <https://data.mendeley.com/datasets/vfz5pz4n8k/8>

The Figures are contained in the excel tables 'RealityCapture_Settings_Results_Renderings' and 'Meshroom_Settings_Results_Renderings'.

Fig. 1 shows the result of the alignment-rate of all datasets (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3) without the usage of the control point feature of the RealityCapture Software (RC). The alignment-rate is given in %. The percentage was calculated from the maximum number of available photos and the photos which RealityCapture was able to align with the given software settings of Table 1. Settings, results and renderings (RC). Table 1 is too large to be shown here. Table 1 can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings').

Fig. 2 shows the result of the alignment-rate of all datasets with the usage of RealityCapture's control point feature (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3). This feature enables to manually merge two or more picture-sets, which RealityCapture was not able to merge automatically with the given settings of Table 1 'Settings (RC)'. The percentage was calculated from the maximum number of available photos and the photos which RealityCapture was able to align with the given software settings of Table 1 'Settings (RC)' and manually setting control points. Table 1 is too large to be shown here. Table 1 can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings').

Fig. 3 shows the total processing time for all data sets (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3) with and without control points in RealityCapture. The total processing time includes the steps: Aligning images, calculating the model and texturing.

Fig. 4 shows the total processing time with control points of all datasets (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3) in RealityCapture (RC).

Fig. 5 shows the total processing time of the data set without the usage of control points (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3). The time needed for the conversion of RAW to TIFF is added here to the data sets of the D810 (D1-D3). In all other figures of the processing

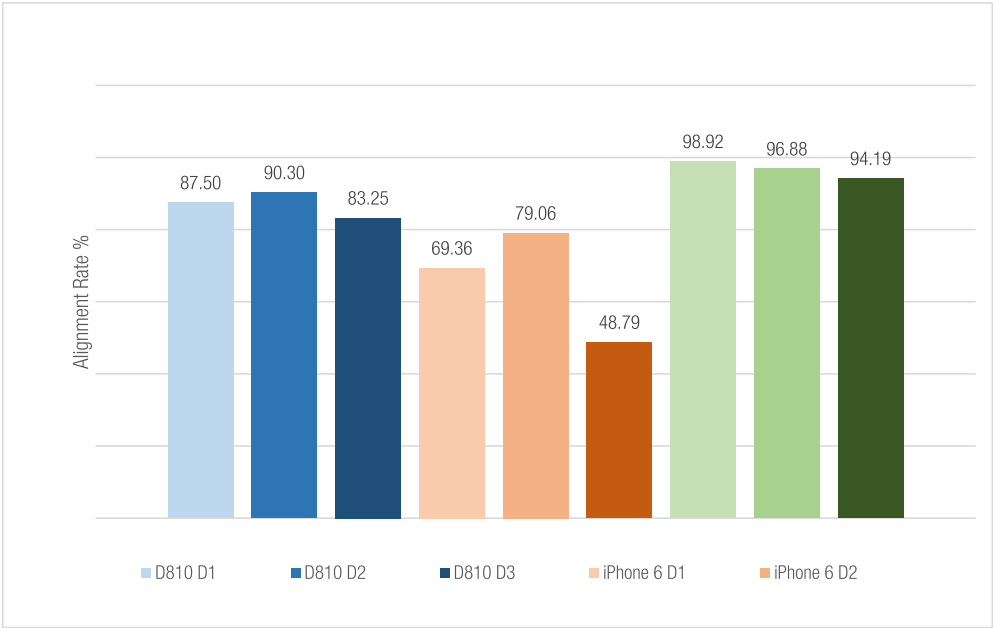


Fig. 2. Alignment-Rate with Control Points (RC).

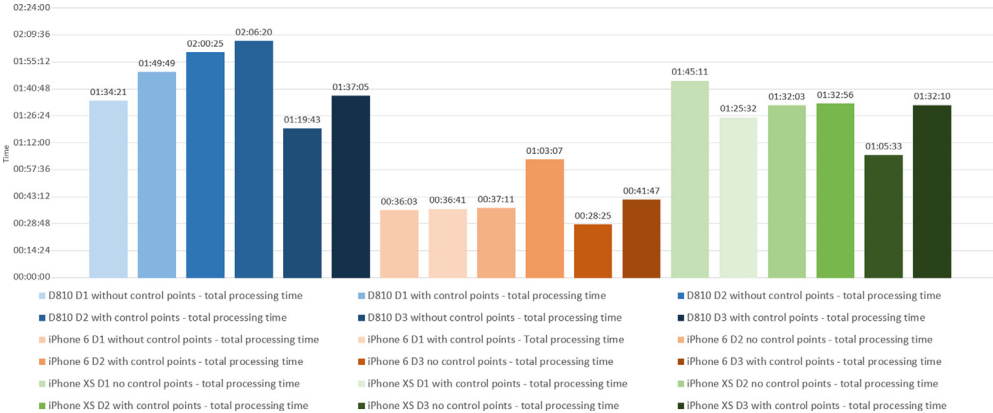


Fig. 3. Total processing time with and without control points (RC).

time, the conversion time (RAW to TIFF) is not taken into account, since it is not part of the photogrammetry process that runs within the software.

Fig. 6 shows the before mentioned conversion time of the RAW to TIFF conversion of the D810 datasets.

Fig. 7 shows the result of the alignment-rate of all datasets (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3) in Meshroom (MR). The alignment-rate is given in %. The percentage was calculated from the maximum number of available photos and the photos which Meshroom was able to align with the given software settings of Table 3. Table 3 'Settings (MR)' (<https://data>.

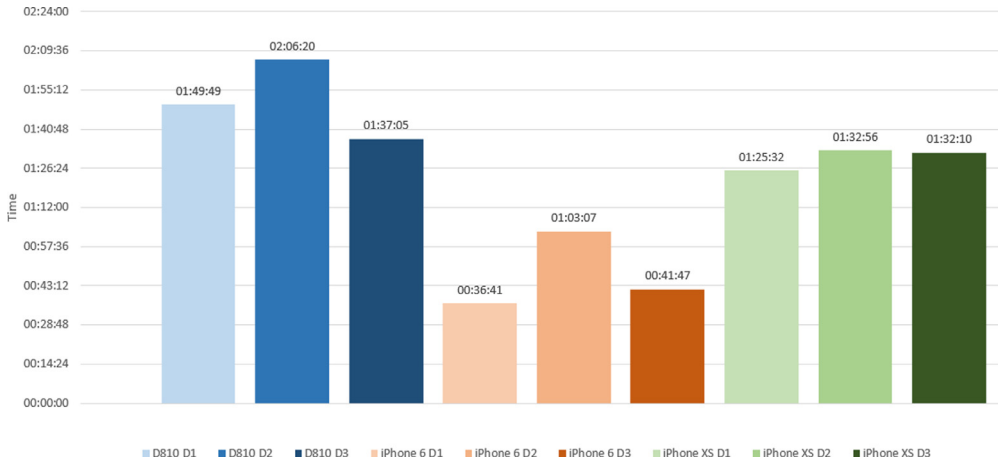


Fig. 4. Total processing time with control points (RC).

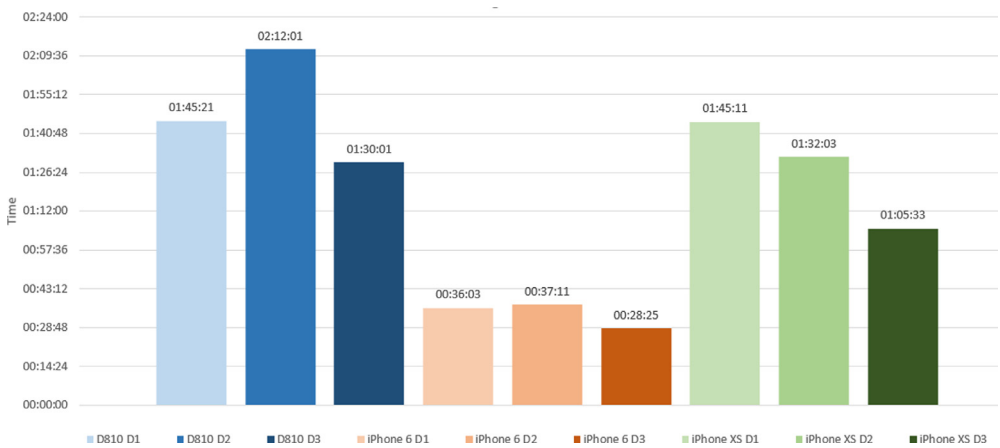


Fig. 5. Total processing time – RAW-TIFF conversion included (without control points Data Set, RC).

mendeley.com/datasets/vfz5pz4n8k/8 in the file 'Meshroom_Settings_Results_Renderings') shows all settings for each node run in Meshroom. Table 3 is too large to be shown here.

Fig. 8 shows the processing time split in substeps for all data sets (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3) in RealityCapture (RC). Fig. 8 is too large to be shown here. The figure can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings').

Fig. 9, visualization of default graph connections shows the detailed connections between the nodes in Meshroom (MR). Containing CameraInit, FeatureExtraction, ImageMatching, FeatureMatching, StructureFromMotion, PrepareDenseScene, DepthMap, DepthMapFilter, Meshing, MeshFiltering and Texturing. Meshroom is an Open-Source-Photogrammetry software which is also used in other projects [1,2].

Fig. 10 shows the total processing time of all data sets (D810 D1-D3, iPhone 6 D1-D3, iPhone XS D1-D3) in Meshroom (MR). It's the analogue representation to Fig. 4, and a direct comparison of the two representations can be made.

Table 1: 'Settings (RC)' shows all settings used in Reality Capture. Table 1 is divided into alignment settings, reconstruction settings and texturing settings. Table 1 is too large to be shown

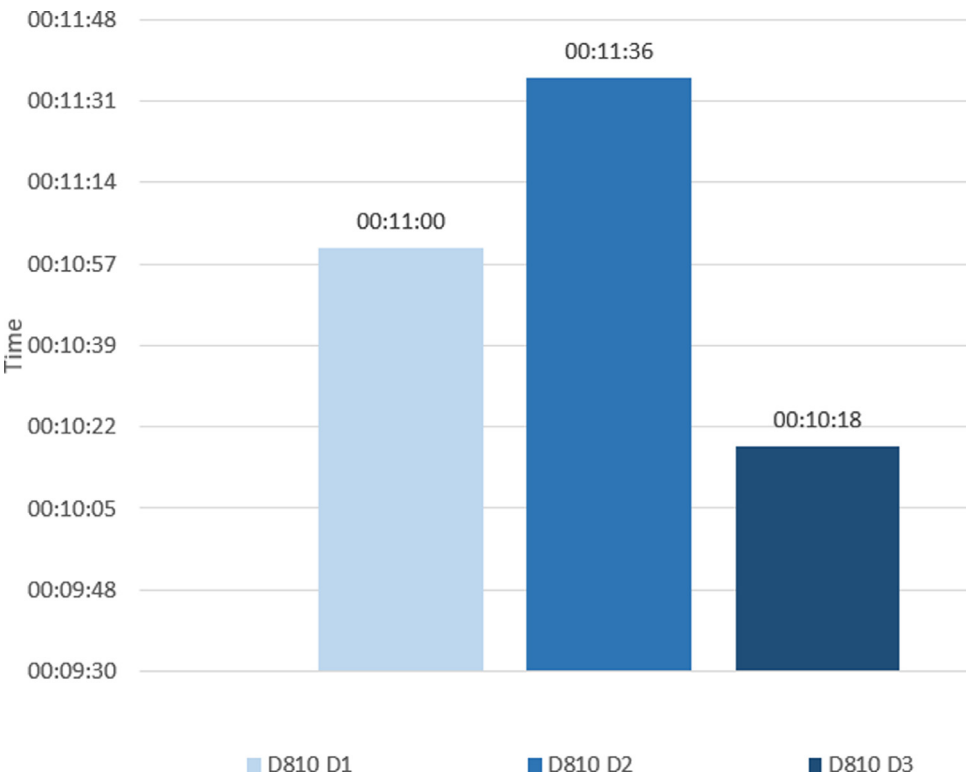


Fig. 6. Processing time of the RAW-TIFF conversion.

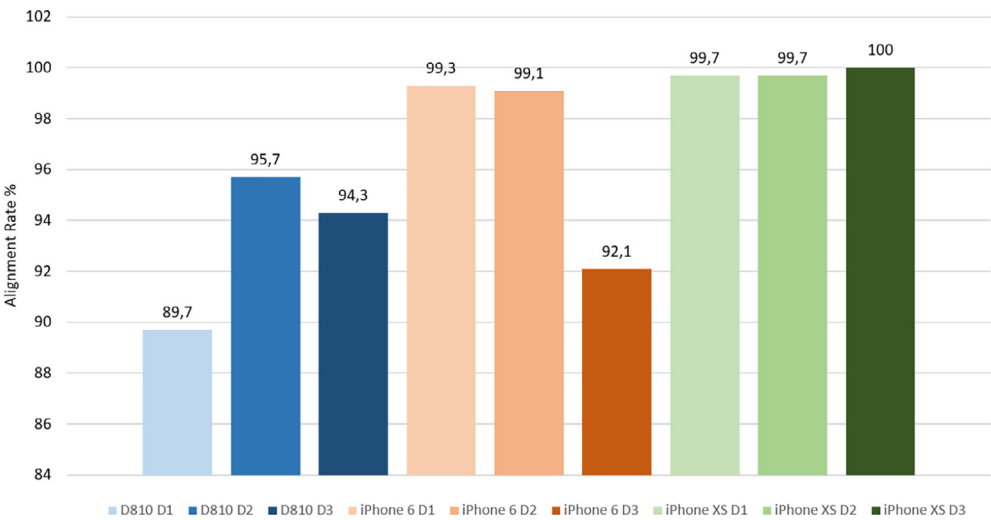


Fig. 7. Alignment-Rate (MR).

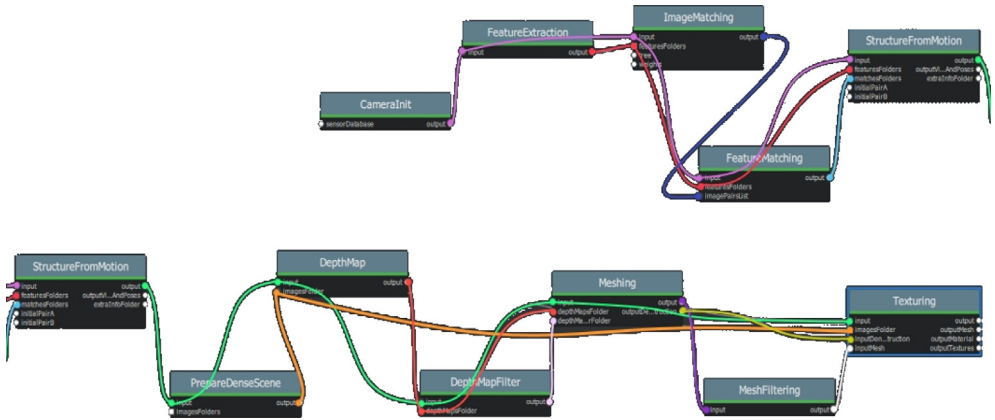


Fig. 9. Total processing time (MR).

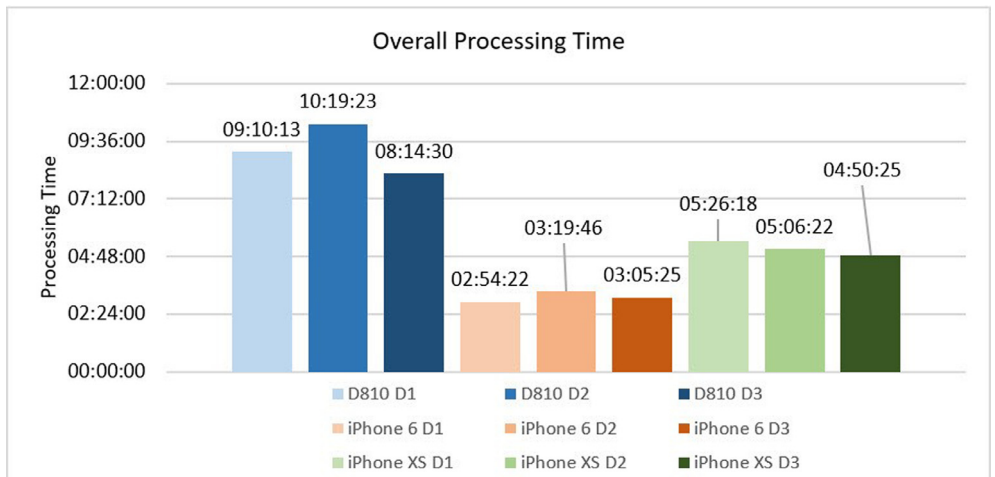


Fig.10. Visualization of default graph connections (MR).

here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings'). These settings can be used to run a future test.

Table 2: 'Renderings of all datasets in RealityCapture' are displayed. Table 2 is too large to be shown here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings'). Each data set was rendered in solely geometry and with texture. In addition, each dataset was calculated with and without control points.

Fig. 11 shows an example from Table 2 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings') of the rendering of D2 (without control points) from the Nikon D810. On the left side of Fig. 11 is the geometry rendering displayed. The textured rendering can be seen on the right side of Fig. 11. For this result 237 pictures were taken with the Nikon D810 and the RealityCapture Software aligned 200 of these 237 images automatically without the usage of the control points feature.

Fig. 12 shows an example from Table 2 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings') of the rendering of D1 (without control points) from the iPhone XS. On the left side of Fig. 12 is the geometry rendering displayed.



Fig. 11. Rendering result of the D2 dataset of the Nikon D810 (RC).



Fig. 12. Rendering result of the D1 dataset of the iPhone XS (RC).



Fig. 13. Rendering result of the D3 dataset of the iPhone 6 (RC).

The textured rendering can be seen on the right side of Fig. 12. For this result 369 pictures were taken with the iPhone XS. For the calculation the RealityCapture Software was able to automatically align 353 of 369 images without the usage of the control points feature to be used for its calculation of the 3D model.

Fig. 13 shows an example from Table 2 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings') of the rendering of D3 (without control points) from the iPhone 6. On the left side of Fig. 13 is the geometry rendering displayed. The

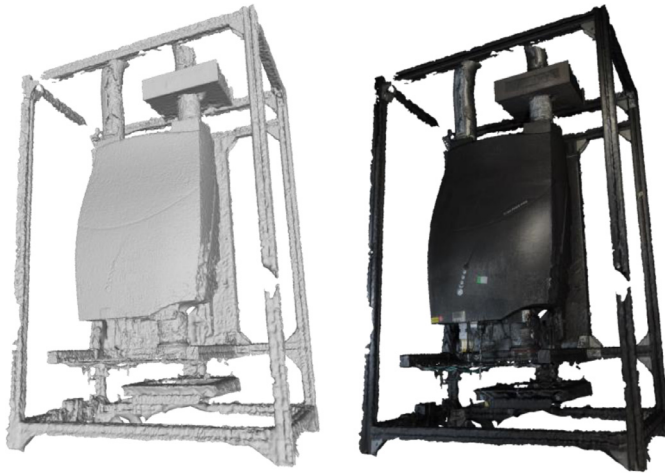


Fig. 14. Rendering result of the D1 dataset of the Nikon D810 (MR).

textured rendering can be seen on the right side of Fig. 13. For this result 330 pictures were taken with the iPhone 6. For its calculation the RealityCapture Software could automatically align 161 of 330 images without the usage of its control points feature.

The comparison shows that much more images are needed with the smartphone and the quality of the rendering still does not come close to the quality of the result of the reflex camera.

Fig. 14 shows an example from Table 5 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'Meshroom_Settings_Results_Renderings') of the rendering of D1 from the Nikon D810. On the left side of Fig. 14 is the geometry rendering displayed. The textured rendering can be seen on the right side of Fig. 14. For this result 224 pictures were taken with the Nikon D810. For the calculation of the 3D Model 201 of 224 images were accepted by the Meshroom Software. Meshroom datasets do not distinguish between 'Without Control Points' and 'Control Points' because there is no way to add images manually using control points in Meshroom.

Fig. 15 shows an example from Table 5 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'Meshroom_Settings_Results_Renderings') of the rendering of D1 from the iPhone XS. On the left side of Fig. 15 is the geometry rendering displayed. The textured rendering can be seen on the right side of Fig. 15. For this result 369 pictures were taken with the iPhone XS. For the calculation 368 of 369 images could be taken into account by the Meshroom Software.

Fig. 16 shows an example from Table 5 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'Meshroom_Settings_Results_Renderings') of the rendering of D1 from the iPhone 6. On the left side of Fig. 16 is the geometry rendering displayed. The textured rendering can be seen on the right side of Fig. 16. For this result 297 pictures were taken with the iPhone 6. For the calculation 295 of 297 images could be used by Meshroom.

The comparison of the renderings show the mesh quality, in terms of accuracy and completeness is better with RealityCapture than with Meshroom.

Table 3 'Settings (MR)' (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'Meshroom_Settings_Results_Renderings') shows all settings for each node run in Meshroom. Table 3 is too large to be shown here. All settings in Meshroom for the corresponding calculation steps are displayed. These settings can be used for a future test.

Table 4.: 'Results (MR)' shows the processing reports for the steps in Meshroom: Structure from motion, meshing, texturing report and the overall processing time. Table 4 is too large to be shown here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'Meshroom_Settings_Results_Renderings'). The recording time, picture count and pixel dimension are included.

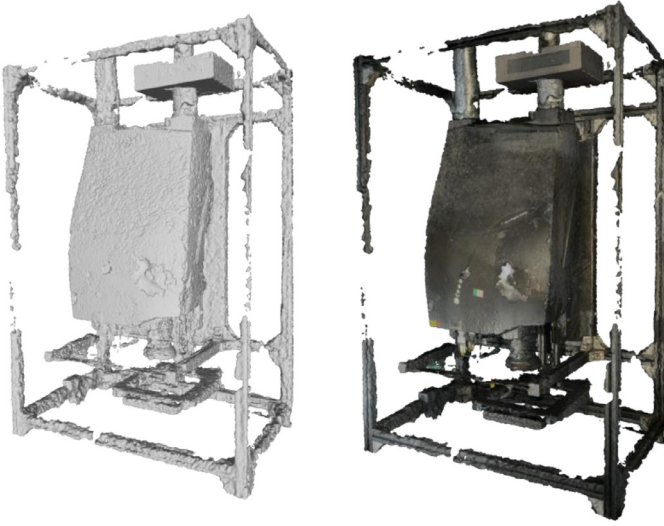


Fig. 15. Rendering result of the D1 dataset of the iPhone XS (MR).

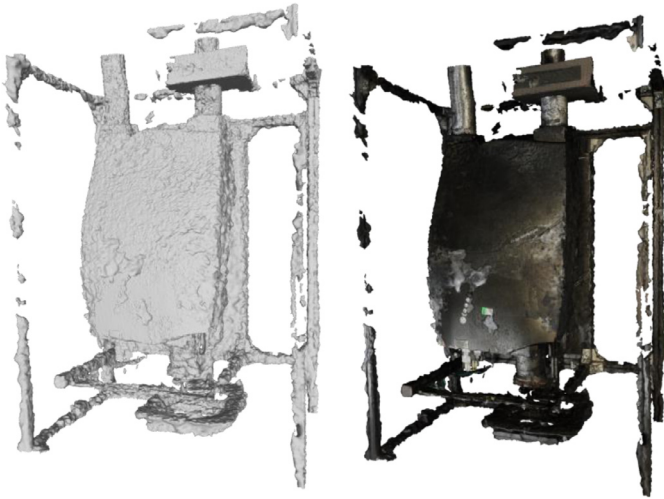


Fig. 16. Rendering result of the D1 dataset of the iPhone 6 (MR).

Table 5.: ‘Renderings of all data sets in Meshroom’ show all rendered geometries and textures of the processed data sets. Table 5 is too large to be shown here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file ‘Meshroom_Settings_Results_Renderings’).

The folder ‘iPhone XS D1 Photos’ in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8>) contains all 369 photos in TIFF. These photos can be used to reproduce the test or to use them for further comparison on another photogrammetry software.

The folder ‘iPhone XS D1 Renderings’ in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8>) contain the geometry and texture renderings associated with the iPhone XS D1 photos. They are the result of the processing in RealityCapture.

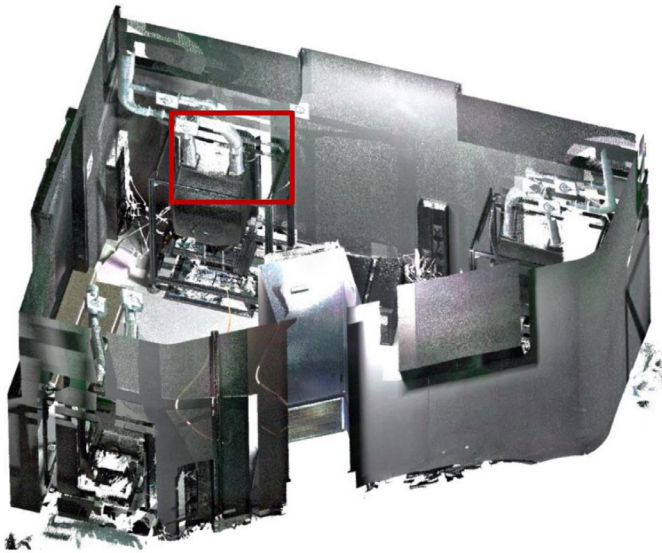


Fig. 17. Basic model represents the initial laser scan.

In Fig. 17 the point cloud of the technical room, which was updated during the experiment, is displayed. The red square marks the original supply air duct without filter. This point cloud is used in the course of the experiment to integrate the partial photogrammetry model and thus to update the point cloud. The file 'Basic model.e57' in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8>) contains the point cloud of the laser scan of the technical room shown in Fig. 17. The laser scanner used was a FARO FOCUS S 350. In the point cloud shown in Fig. 17, the upper part was cut off at the top so that you can see into the technical room. In the original point cloud, the ceiling of the technical room is present.

Fig. 18 shows the updated point cloud. For this purpose the photogrammetric model D1 of the Nikon D810 was integrated into the 'Basic model'. It can be recognized the point cloud in the area of the photogrammetry model is significantly denser than the original point cloud of the laser scan. The file 'Updated PointCloud.e57' in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8>) contains the laser scan of the technical room with the integrated photogrammetry mesh. This represents the updated model in the presented research.

2. Experimental Design, Materials, and Methods

The data presented here are part of an evaluation to compare the photogrammetric results of different hardware devices (Nikon D810, iPhone XS and iPhone 6). Furthermore, a commercial photogrammetry software RealityCapture and the open source photogrammetry software Meshroom were compared. Afterwards it was a matter of integrating the results of photogrammetry into the point cloud of a laser scan [3]. The comparison parameters were extracted from the log data. The software RealityCapture BETA 1.0.3.9696 ppi and Meshroom 2019 2.0 were used.

The features of the employed PC system are shown in Table 6. Attempts were made to make similar settings in RealityCapture and Meshroom to achieve a realistic comparison of the calculation times. The exact settings used in RealityCapture are shown in Table 1 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file 'RealityCapture_Settings_Results_Renderings') and the settings used in Meshroom are shown in Table 3 (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file "Meshroom_Settings_Results_Renderings"). Note that there are a few settings that are different or that could only be set in one software.



Fig. 18. Updated point cloud.

Table 6
PC system used for the calculation.

| Category | Feature |
|------------------|--|
| CPU | Intel® Core™ i7-6700 CPU @ 3.40GHz 3.31 GHz |
| RAM | 32 GB |
| GPU | NVIDIA GeForce GTX980 Ti |
| Operating system | Windows 10 Pro Version 1809 64 Bit |

Table 7 ‘Results (RC)’ contains in the report sections all information of the processing results. Table 7 is split in the sections alignment report, reconstruction report and texturing report. The Table also includes the processing time for the photogrammetry models, which is the basis for the figures shown. Table 7 is too large to be shown here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file ‘RealityCapture_Settings_Results_Renderings’).

Table 8 ‘Data sets (RC)’ includes the recording time, picture count and pixel dimension of the recording with all 3 devices: Nikon D810, iPhone6, iPhone XS. Table 8 provides information about the data source (photos), which is the basis for the calculations in the RC and MR software. Table 8 is too large to be shown here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file ‘RealityCapture_Settings_Results_Renderings’). As mentioned in RC and MR the same Datasets were used. Thus, Table 8 ‘Data sets (RC)’ and Table 9 ‘Data sets (MR)’ are identical. Also, Table 9 is too large to be shown here. It can be found in the repository (<https://data.mendeley.com/datasets/vfz5pz4n8k/8> in the file ‘Meshroom_Settings_Results_Renderings’).

The data provided here is meant to show that low-cost hardware can be used to update a point cloud in a factory environment. This data was generated during the development of a method for updating digital factory models [4]. The use of photogrammetry in construction projects has given rise to other methods [5]. Once the digital building model is updated, it can be used for further applications on the construction site by means of visualization technologies such as augmented reality [6,7,8].

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Acknowledgments

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