3D modelling of the castle Neu-Wildon

Applying UAV-based photogrammetry, terrestrial photogrammetry and terrestrial laser scanning – a comparative study

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Introduction

In 2020 renovation work and protective measures were carried out at the castle complex Neu-Wildon. During this work the whole site was not only scanned with a Leica RTC360 laser scanner, but also captured with a Nikon D800 digital camera for terrestrial photogrammetry and additionally surveyed applying UAV-based aerial photogrammetry using a quadrocopter DJI Phantom 4. The main aim of the survey was to document the remaining parts of the structure in every detail to provide a solid data foundation for scientific building research. On the basis of these datasets a 3D reconstruction of the castle has been attempted.

Control points

To accomplish a reasonable accuracy level with every reality capture technique the usage of control points is inevitable. Therefore, 19 ground marker plates and 250 wall markers have been measured from 17 setup points with a geodetic total station. The setup points have been adjusted with redundant measurements in a geodetic net to reach a position accuracy of 1–2 mm. These control points served as the geometric reference for all used surveying methods.

Geometrical deviation between the 3D results

49 laser scans have been taken with the Leica scanner RTC360 on site. According to the instrument's datasheet and proved by internal quality checks the scanner fulfils an accuracy of 1 mm + 10 ppm (e.g. 5.3 mm @ 40 m). The alignment of the scans was established with cloud to cloud approaches with a minimal overlap of 28% and stabilized by 17 equally distributed scanning targets (i.e. control points) on the setup points of the total station. The overall error at the target plates after

the adjustment was 4 mm and therefore provides a homogenous geometrical reference with an object accuracy of below one centimetre.

The internal camera of the DJI Phantom 4 acquired digital images with a frame size of 4000 × 3000 pixels. The pixel size of 1.56 µm relates to a ground resolution of 18 mm at a flying height of 43 m above ground. The images have also aligned and georeferenced with the ground markers using custom SFM software.

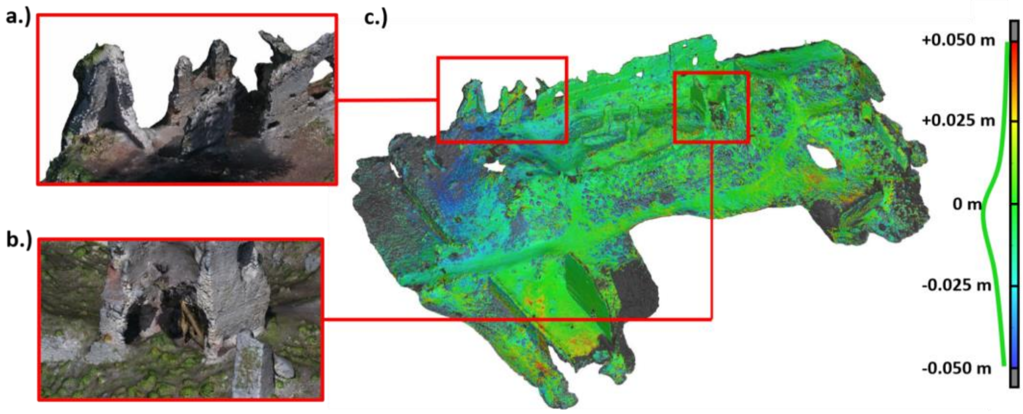

Fig. 1. Cloud2Mesh comparison between laser scan (cloud) and UAV (mesh) data with detail images of a) the northern living quarters and b) the kitchen

The Cloud (Scan) to Mesh (UAV) comparison in Figure 1c shows that 75% of all deviations are within ± 2.5 cm (histogram at the scale bar). The best results can be obtained from open ground without vegetation and from exposed walls. However, due to the limited coverage from above, narrow areas as seen in the northern living quarters (Fig. 1a) or covered areas like the kitchens storage room (Fig. 1b) have vast errors where the meshing algorithm has smoothed and auto filled these areas. The most prominent parts of the structure have been captured with 1088 images using the Nikon D800 digital camera. The images have also been aligned and georeferenced with the wall markers using the same SFM software. The comparison of the laser scan point cloud with the model derived from terrestrial photogrammetry shows a high congruence (few millimetres) in the central area where nearly orthogonal viewing directions were possible. In the palas, where the dip angles were steeper, due to space limitations, a systematic deviation occurs of up to two centimetres at the top region of the wall.

Level of detail

Figure 2 shows a comparison between all three observation methods. Therefore, cutting planes have been calculated through all 3D models and displayed in Figure 2d.

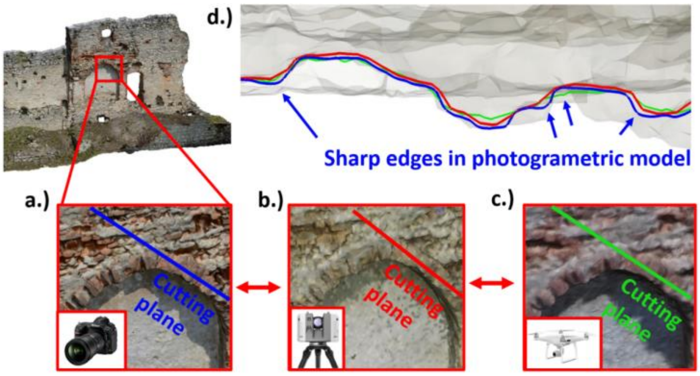

Fig. 2. Comparision between the different observation methods a) SLR model b) TLS model c) UAV model d) by using geometric cutting lines through the obtained 3D models

Regarding the obtained UAV-based model in Figure 2c, single bricks can be hardly distinguished and due to the camera look direction from above many small 3D features, such as pole holes, shafts and small windows, are only represented as black spots in the texture. Therefore, it is not suitable for detailed investigations beyond obtaining a digital surface model.

The laser scan model in Figure 2b has a mean point distribution of 5mm on the object which leads to better resolution compared to the UAV but also single bricks are hard to be identified. Also for the adequate 3D representation of all feature parts without any obstruction a much higher number of scans would have been needed which would have increased the raw data enormously on the other hand. Terrestrial photogrammetry has the advantage that 3D features are covered from various angles, providing more complete models. In Figure 2a it can be seen that the camera resolution captures the different materials of the wall and has sharp corners between adjacent objects. Only here the required level of detail for scientific building research is met.

3D modelling

According to the visible construction features and on the basis of historic paintings and plans (as seen in Figure 3a & 3b) a reconstruction of the initial state of the castle at the end of the 16th century has been attempted. The large scale geometrical features, such as wall lines, wall thickness and heights, have been extracted from the laser scan model. The small scale features, such as windows, pole holes and floor levels, have been modelled according to the highly detailed Nikon camera-based model. Due to the lack of large scale archaeological excavations a major part of the 3D model had to be extrapolated with logical considerations based on geometrical and topological necessities. For sustaining these extrapolations, the model has been accessed with Virtual Reality gear during the process, as seen in Figure 3d, to check the feasibility of floors, windows and passage ways from a visitor’s point of view.

Therefore, the 3D model in Figure 3c describes a plausible castle complex which is within the tolerance of the remaining structure and the available historic sources and may inspire further excavations for testing these working hypotheses.

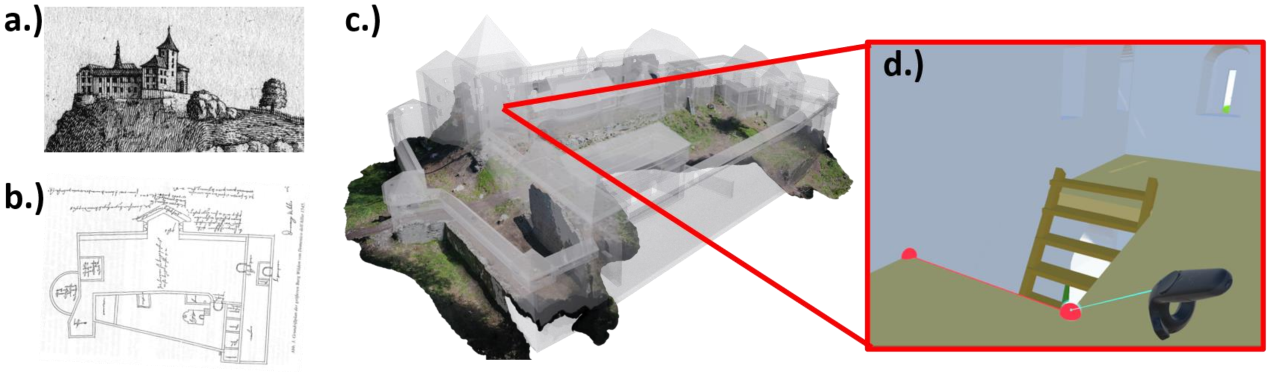

Fig. 3. View of the c) reconstructed 3D model according to a) a Copperplate by Vischer and b) a Plan of Domenico deU'Allio and d) a VR View while taking in-scene measurements

Result of the project

For the first time the whole castle complex has been captured in 3D and the remaining (visible) structures have been documented. The datasets have been shared with the castle owner and are accessible to other institutions for further building research.

The obtained 3D reconstruction describes the current state of the building research and may serve as basis for further reconstruction work. While creating this 3D model, areas have been revealed which need more attention in future research and excavation activities such as the area in front of the palas and the main gate with its surrounding buildings.

Lessons learned

This study has shown that:

- the UAV-based survey covers a wide area with a reasonable accuracy of a few centimetres for open areas. However, the UAV based model suffers from vast errors in obstructed and narrow areas of the historic building complex and was not suitable for further research.
- terrestrial photogrammetry can provide a highly detailed model, although geometrical insufficiencies in narrow spaces can be expected due to steep camera angles.
- terrestrial laser scanning delivers a consistent geometrical 3D model with a reasonable level of detail for geodetic monitoring but is not suitable for the representation of historic brickwork. In order to achieve high geometrical accuracy and the right level of detail at the same time, a combination of terrestrial laser scanning and terrestrial photogrammetry has to be used for the optimal result.
- Virtual Reality Gear is suitable for making design decisions during virtual 3D reconstruction.

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