# High-Speed 3D-Documentation of Schönbrunn Palace

## Pushing technological boarders in completeness, resolution, and accuracy

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## Introduction and Related Work

*Schönbrunn Palace* was the main summer residence of the Austrian emperor and is located in Vienna, Austria. Since 1996, it is listed as *UNESCO World Heritage Site* and, in addition, being one of the most important and most visited touristic hot-spots of Vienna, special requirements on continuous monitoring and documentation are given. Especially ongoing restoration and construction work require detailed, complete and accurate 3D-documentation.

Since 2000, the *Schloß Schönbrunn Kultur- und BetriebsgesmbH* which is operating and managing the heritage site established a continuous procedure for 3D-documentation of all objects being restored. Terrestrial (TLS) and airborne laserscanning (ALS) as well as image based structure from motion (SFM) is commonly used to document the status before the restoration as foundation for decision making, and the status after the restoration for long-time monitoring as well as for the case that something is destroyed by an unforeseen event.

For small to medium sized objects (sculptures, fountains, …) or for parts of buildings (some 100 m of facades, distinct parts of a roof, …), this can be realized using conventional workflows and technologies at an economically feasible effort. The complete documentation of large and complex buildings however caused a huge effort and high costs so far.

In this contribution, we describe a highly automated approach, based on cutting edge technology to enable the 3D-documentation including high-resolution image acquisition of the exterior of the main building of *Schönbrunn Palace* (size: ~180 x 60 m / 6,800m²; façade length: ~550 m) within one day.

## Data Acquisition and Processing

The data acquisition is based on the following three steps:

1. Geodetic network measurement providing precise positions of 14 retroreflecting marker points defining a local reference frame in relation to the Austrian reference frame.
2. Terrestrial Laserscanning (TLS) using a high-speed and high-resolution *RIEGL VZ-400i* for capturing the facades in 3D and colour.

3. UAV-based image acquisition using a high-resolution *Phase One iXM-100* medium format camera for capturing the roof in 3D and colour.

In this case, the work was carried out on 3 days in March and April 2020. The entire TLS data acquisition was carried out by a single operator within 6.5 hours. For the UAV operation, it is advisable to have two persons, one controlling the UAV and one checking the camera settings and viewing positions. The geodetic network can be realized by one operator, however, two are advisable for efficiency reasons (i.e. switching totalstation and mirrors between the tripods). Therefore, considering a team of 4-5 people, the complete data capturing would be possible within one working day as the different processes do not handicap each other. Figure 1 shows the TLS with camera and the UAV equipped with the *Phase One* camera.

*a* *b*

*Fig. 1. a) TLS RIEGL VZ-400i; b) DJI Matrice 600 pro with Phase One iXM-100 camera*

## Terrestrial Laserscanning

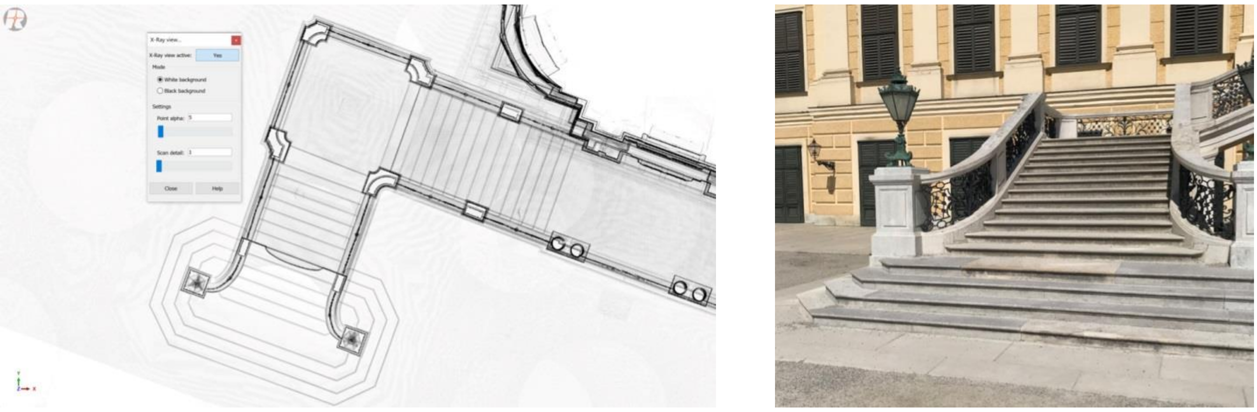
The typical workflow of the eye-safe *RIEGL* VZ-400i laser scanner used here is to acquire one so-called panoramic scan after another. The scanning parameters have been selected to maximize the recording efficiency. A so-called "Panorama40" scan (360° x 100° field of view, 40 millidegrees resolution) requires 45 seconds scanning time. An average of 22.5 million measurements per scan is performed. The spatial resolution of the measuring points at a distance of 10 meters is 7 mm. Five 45-megapixel photos are taken per scan. The time required for the 292 scanning positions was 6.5 hours for a single operator. Table 1 lists the specification of the scanner.

| | |
|---|---|
| Laser scanner | RIEGL VZ-400i |
| Field of view of the laser scanner | 100° vertical x 360° horizontal |
| Angular resolution | 0.040° (7 mm @ 10 m distance) |
| Precision of range measurement | 3 mm |
| Attached photo camera | Nikon D-850 (14 mm lens), 45 MPix / image |

*Table 1. TLS specification*

Already within the laser scanner it is possible to combine the scan data of one scan after the other, thus to "register" the scan positions. This process is multi-stage, using a built-in GNSS receiver, built-in IMU (inertial measurement unit), and the subsequent *Fourier Transformation* and *ICP* (iterative closest point) algorithms (Ullrich 2017).

The processing of the scan data includes filtering the scans, the fine block adjustment of all scan positions ("Multistation Adjustment") by the use of the geo-referenced markers, colorize the scans from the photos and homogenization of the data (using Octree Extractor). A detail of the merged scandata of the southern staircase is shown in Fig. 2



*a* *b*

*Fig. 2. a) laser scan and b) photograph of the southern staircase*

## UAV-based High-Resolution Camera

A variety of UAV-based data acquisition systems do exist ranging from "low-budget" systems using consumer camera-drones (e.g. Sun and Zhang 2019) to heavy payload drones with calibrated, high-resolution cameras and direct georeferencing sensors. The specification of the *Phase One iXM-100* medium format camera used in this project is given in table 2.

| | |
|---|---|
| Camera | Phase One iXM-100 |
| Lens | RSM 35mm f/5.6 (63 x 49,4° opening angle) |
| Image resolution | 100 MPix (11,664x8,750 Pixel) |
| Effective sensor size | 43.9 x 32.9 mm |

*Table 2. UAV-Camera Specification*

At a mean flight height of 35 m above the roof landscape, an image resolution of 3.7 mm per pixel could be achieved. The entire roof was captured with a vertical camera position using waypoint flight. In addition, 45° tilted viewing direction towards the façade was used to complete the area along the balustrade. Due to the lighting conditions, it was necessary to plan the flights w.r.t. the position of the sun to prevent hard shadows.

## Results

The current result is a voxel based point cloud with 1 cm resolution representing the façade area and a high-resolution mesh including texture of the roof landscape. In high-up areas of the facades which cannot be seen from the ground, completeness was achieved using SFM point-clouds from the UAV flight. Figure 3 shows the textured model of the main building of *Schönbrunn Palace*.

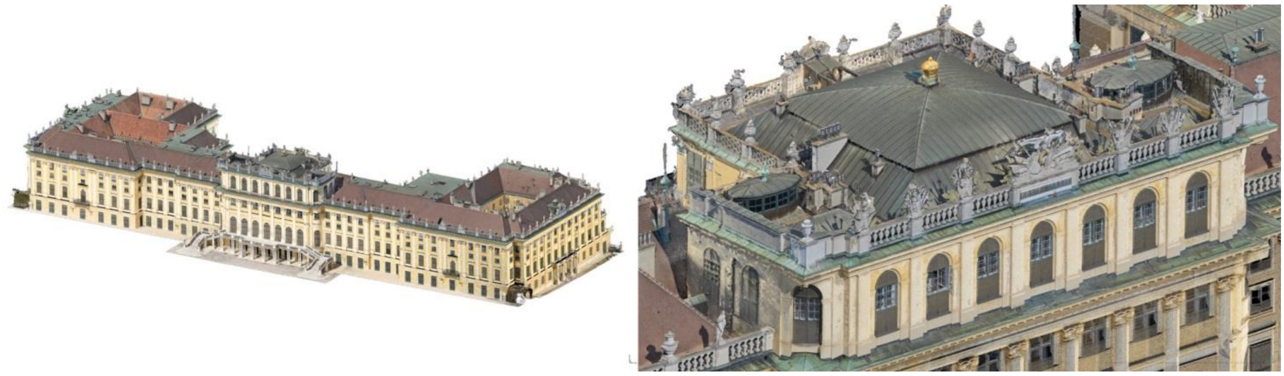


*Fig. 3. Textured 3D-model of Schönbrunn Palace*

We evaluated the achievable accuracy. The georeferencing was realized as follows:

- Multistation adjustment of 292 scanning positions using real-time GNSS/IMU position and orientation information as input and applying a sophisticated scan-wise co-registration approach (inner accuracy: ±1 mm)
- 14 marker of a geodetic network defining the reference frame (inner accuracy: ±6 mm)
- Bundle-block adjustment of 458 cameras and 57 ground control points measured by GNSS and totalstation (inner accuracy: ±10 mm)
- Fine registration of SFM-point-cloud to TLS-point-cloud using identical, planar areas (facade, ground, roof) (absolute accuracy: ±10 mm)

### Discussion and Outlook

This example demonstrates that the integration of cutting-edge, high-resolution terrestrial and airborne data acquisition enables a complete documentation of huge and high objects in a very fast and hence efficient manner. The main building of *Schönbrunn Palace* can be captured in 3D within 1 day at a resolution and absolute accuracy of 1 cm and with 3.6 mm texture. We are aware, that compared to other “low-budget” approaches, the demand for the equipment is comparably high. However, considering restricted time budget (e.g. closing areas for tourists, weather conditions, legal restrictions, …), and due to the fact that field work is typically expensive, the high costs of the equipment can be overcome quickly, especially if high accuracy is required. Due to the high completeness, the data is well suited for automated processing based on artificial intelligence and machine learning to derive data for Building Information Modeling (BIM).

### Acknowledgments

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