3D laser scanning of remote temple sites in Nepal

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Introduction

Compared to geodetic methods based on total stations or GNSS instruments, laser scanning is a relatively new technology with its commercialisation in the early 2000s. However, the large-scale transformation of entire sites into highly detailed 3D data sets, has found many applications in Structural Health Monitoring, Building Information Modelling and Virtual Heritage.

In the cultural heritage sector fast acquisition methods for accurate 3D data, which can be seen for instance in Pavlidis (2007), behold many advantages for documentation and building analysis compared to conventional approaches.

At the Graz University of Technology, the documentation of heritage buildings in Asia has a long tradition with the surveying projects of Robert Kostka (2020) from the geodetic institutes. The Institute of Architectural Theory, History of Art and Cultural Studies (akk) has an extensive collection of research material on Buddhist architecture in the Western Himalayas, which has been gathered for more than two decades. The results are presented on the project´s website and published in the books by Carmen Auer and Neuwirth (2013, 2015 & 2021).

In 2022 a cooperation between the Institute of Architectural Theory, History of Art and Cultural Studies (akk) and the Institute of Engineering Geodesy and Measurement Systems (IGMS) has been established within the FWF Project “Buddhist Architecture in Western Himalayas” in order to integrate modern surveying techniques and workflows into the existing methodology of conventional building research. The aim of this ongoing interdisciplinary work is to explore significant Buddhist temple sites in Upper Dolpo, a remote area in Nepal, and to document them with modern 3D laser scanning technology. This should provide a solid data foundation to study architectural connections in topologies of sites and for further building research of the scientific community.

Fieldtrip in 2022

Dolpo is a mountainous region in the north-west of Nepal. It encloses the Shey-Phoksundo national park and extends up to the Tibetan border. From the municipal village Dunai, the remote temple sites can be only accessed by footways or helicopter. In this project, all resources and necessary equipment had to be transported into the Upper Dolpo region with a mule caravan up to an average height of over 4000 meters above see-level. A 45-day trip was planned in the area to have sufficient time at each site (see Figure 1).

A special focus was placed on the documentation of Shey-Monastery, Samling-Monastery and the Nesar temple in Bijer, which represent important Buddhist sites of Buddhist in the area today.

Surveying Methods

Due to low costs, photogrammetry has become a frequently used tool in Archaeology and Virtual Heritage. A feasibility study (Dhonju et. al, 2017) has already shown that large scale photogrammetry and crowdsourcing can be beneficial for the fast capturing of Nepalese heritage sites with moderate 3D accuracy.

To reach a higher accuracy within a few millimetres, the documentation strategy in the project was based on a combination of highly accurate laser scan data *(Leica RTC360)* and photogrammetric images. The laser scans have been pre-registered in field, and post-processed in the Leica Register 360 software.

The registration is based on cloud-to-cloud registrations (in order to have a high mobility in the measurement setups) as well as stable reference points. These coordinates of the ground control points were determined with redundant measurements using a geodetic total station *(TS11)* in local geodetic network configuration (see Figure 2).

The high altitude and the atmospherical conditions required corrections of the electronical distance measurements of the total station of over 100 ppm. This corresponds to corrections of more than 1 cm for a measurement distance of 100 meters.

Another challenge was the power supply of all electronical devices with solar panels, in this remote area. Especially for the drone surveys, the low air density of high altitudes resulted in an increased power consumption and reduced duration of the batteries of about 50%.

The texturing of the 3D data sets was achieved in the indoor areas with the integrated HDR cameras of the laser scanner. The resolution of the panorama images was sufficient for a mean object distance of 2 meters (1 pixel @ 2 m ~ 1 mm^2). Additionally, artificial lighting was mounted on the scanner to achieve a more homogeneous lighting in the rooms. In the outdoor areas the laser scans were merged with terrestrial and airborne images to cover also exposed areas and to gather vast terrain information.

The combination of the laser scans and the images was achieved with software *RealtyCapturer*. A textured mesh with the camera locations can be seen in Figure 3.

Further Research

The datasets in this project will be the foundation for the upcoming architectural research and the investigations of the construction phases, the historical development of the temple sites and for the assessment of the structural integrity.

From a technical point of view, the further development of 3D data processing strategies in the cultural heritage sector is a widely discussed topic. The availability of accurate 3D laser scan data and the degree of digitalisation in modern surveying methods are changing paradigms the heritage preservation and building research. Object orientated software approaches for the use of semantic 3D models are already emerging in these scientific fields (e.g. Croce et. al., 2023).

It will be part of future geodetic research to investigate automatic processing strategies, which may be applicable to the Nepalese temple sites. Furthermore, 3D approaches with Virtual Reality will be tested to support the well-established 2D analysis methods.

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